ALION

CONSULTING REPORT

ANALYSIS OF INTERFERENCE TO ELECTRONIC NEWS GATHERING RECEIVERS FROM PROPOSED 6 GHz RLAN TRANSMITTERS

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14. ABSTRACT

The Federal Communications Commission in Docket 18-295 (FCC 18-147 Notice of Proposed Rulemaking released October 24, 2018) proposes rules for use of unlicensed devices in portions of the 6 GHz frequency band. Radio Local Area Network (RLAN) Wi-Fi wireless routers/transmitters could interfere with existing electronic news gathering (ENG) receiving systems. The National Association of Broadcasters (NAB) requested analysis support from Alion Science and Technology (Alion) to predict possible electromagnetic interference (EMI). Alion performed EMI analyses for selected representative scenarios. The Alion analyses predicted harmful RLAN EMI that could potentially result in degradation or complete loss of ENG video signals.

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EXECUTIVE SUMMARY

The Federal Communications Commission (FCC) in Docket 18-295 (FCC 18-147 Notice of Proposed Rulemaking (NPRM) released October 24, 2018) proposes rules to promote new opportunities for unlicensed use in portions of the 1200 MHz of spectrum in the 5.925-7.125 GHz (6 GHz) frequency band while ensuring the performance of licensed services operating in the band is not degraded by interference. Unlicensed Radio Local Area Network (RLAN) Wi-Fi wireless routers/transmitters will provide increased internet connectivity at a low cost in the 6 GHz frequency band. These unlicensed RLAN Wi-Fi wireless routers/transmitters are expected to follow the technical rules for Unlicensed National Information Infrastructure (U-NII) devices operating in the 2 GHz and 5 GHz bands.

The Broadcast Auxiliary Service (BAS) and Local Television Transmission Service (LTTS) are radio services licensed under FCC Part 74 and Part 101 and are used to gather and broadcast news stories and images. The BAS and LTTS radio services support television (TV) station operations under the mobile allocations in the 6.425-6.525 GHz (U-NII-6) and 6.875-7.125 GHz (U-NII-8) bands. Mobile vans are used to transmit electronic news gathering (ENG) program material from event locations to central receive sites in a town or city. Local TV stations and national news organizations obtain the program material from the central receive sites via microwave or optical fiber links.

Because the RLAN Wi-Fi transmitters are proposed to operate in the same frequency bands as the TV service receivers, electromagnetic interference (EMI) to the TV service receivers is a possibility. The National Association of Broadcasters (NAB) requested Alion Science and Technology (Alion) analyze the potential for EMI from 6 GHz RLANs to ENG receiving systems.

Alion performed EMI analyses for selected representative scenarios. These urban/suburban scenarios consisted of central ENG receive sites, ENG mobile truck locations, and an interior ENG receiver location. Each of these ENG deployments was assumed to be in the proximity of the proposed 6 GHz RLAN Wi-Fi transmitters. San Diego, CA, Washington, DC, and Prince George's (PG) County, Maryland were chosen as representative sites. The interior scenario consisted of an ENG receiver and RLAN Wi-Fi transmitters in the Chamber of the US House of Representatives.

The Alion analyses predicted harmful RLAN EMI for each of the ENG system deployment use cases. This EMI could potentially result in degradation or complete loss of ENG video signals. For the ENG central receive sites near San Diego, CA and Washington, DC there were many cases of significant continuous or near-continuous interference. This occurred most frequently for an RLAN activity factor of 10%, but also occurred for a low activity factor of 0.44%. The ENG central receive sites, given their high antenna heights, were line-of-sight (LOS) to many RLANs resulting in the high undesired signal levels as well as a high incidence of interference.

For the ENG truck deployment cases investigated, the number of RLAN LOS links (and subsequently the probability of interference) was dependent upon the relationship between the RLAN antenna heights, the ENG antenna heights, and the heights of the surrounding buildings. Significant intermittent EMI was predicted for an activity factor of 10% and an ENG truck antenna height of 15 m. Much less interference was predicted for the low activity factor of 0.44% and lower ENG truck antenna height of 1.5 m, but even in these cases the interference threshold was still exceeded. LOS blockage was greater in Washington, DC than in PG County, consequently the rate of EMI incidence increased for the PG Country ENG truck deployment.

The interior analysis, based upon a single interior receiver on the balcony of the chamber of the US House of Representatives, found interference occurred when the activity factor and the on-tune circumstances coincided to increase the possibility of EMI. However, adjacent channel signals were determined to be a significant component in likely EMI interactions between the 6 GHz RLAN transmit routers in the US House of Representatives and the ENG receiver in the chamber.

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GLOSSARY

AGC	Army Geospatial Center
AGL	Above Ground Level
AP	Access Point
A/V	Audio/Video
BAS	Broadcast Auxiliary Service
BEL	Building Entry Loss
dB	Decibel
dBi	Decibels relative to isotropic radiator
dBm	Decibels referenced to a milliwatt
dBW	Decibels referenced to a watt
deg	Degrees
DVB-T	Digital Video Broadcast –Terrestrial
EIRP	Equivalent Isotropically Radiated Power
EMI	Electromagnetic interference
ENG	Electronic News Gathering
FCC	Federal Communications Commission
FDR	Frequency Dependent Rejection
GIS	Geographic Information System
GHz	Gigahertz
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
I/N	Interference-to-Noise
ITU	International Telecommunications Union
J	Joules
K	Degrees Kelvin
km	Kilometers
LiDAR	Light Detection and Ranging
LOS	Line-of-Sight
LMST	Link Modulation Standard Terrestrial
LNB	Low Noise Block downconverter
LTTS	Local Television Transmission Service

m	Meters
MHz	Megahertz
MSAM	Microcomputer Spectrum Analysis Models
NAB	National Association of Broadcasters
NLOS	Non-Line-of-Sight
NPRM	Notice of Proposed Rulemaking
NTIA	National Telecommunications and Information Administration
OFR	Off-frequency rejection
OMB	Office of Management and Budget
OOBE	Out-of-Band Emissions
OTR	On-tune rejection
PG	Prince George’s
PGCC	Prince George’s County Courthouse
RF	Radio Frequency
RLAN	Radio Local Area Network
TV	Television
U-NII	Unlicensed National Information Infrastructure

1.0 INTRODUCTION

1.1 BACKGROUND

The Federal Communications Commission (FCC) in Docket 18-295 (FCC 18-147 Notice of Proposed Rulemaking (NPRM) released October 24, 2018) proposes rules to promote new opportunities for unlicensed use in portions of the 1200 MHz of spectrum in the 5.925-7.125 GHz (6 GHz) frequency band while ensuring the performance of licensed services operating in the band is not degraded by interference. Unlicensed Radio Local Area Network (RLAN) Wi-Fi wireless routers/transmitters will provide increased internet connectivity at a low cost in the 6 GHz frequency band. These unlicensed RLAN Wi-Fi wireless routers/transmitters are expected to follow the technical rules for Unlicensed National Information Infrastructure (U-NII) devices operating in the 2 GHz and 5 GHz bands. Under the proposed rules, Wi-Fi routers would be permitted to operate in the 6.425-6.525 GHz (U-NII-6) and 6.875-7.125 GHz (U-NII-8) sub-bands currently allocated to broadcast and television radio services.

The Broadcast Auxiliary Service (BAS) and the Local Television Transmission Service (LTTS) radio services are licensed under FCC Part 74 and Part 101 and are used to gather broadcast news stories and images. BAS and LTTS radio services operate under mobile allocations in the 6.425-6.525 GHz (U-NII-6) and 6.875-7.125 GHz (U-NII-8) bands. Television (TV) crews and reporters transmit electronic news gathering (ENG) stories and images from events at area locations back to the town or city TV studio. Typically, a news team in the field using a portable camera sends an audio/video (A/V) digital stream to a nearby mobile TV van. Subsequently, the TV van relays the digital stream to a fixed central receive site on a mountain or tall building that commands line of sight (LOS) views of the town or city. Microwave links or fiber optic cables are used to transfer the digital stream from the central receive site to the local TV station. In many cases TV service transmitters are licensed to operate across the frequency band and are assigned coverage areas typically defined by either radii from latitude/longitude (lat/long) points or hemispheres centered on lat/long points.

Because the RLAN Wi-Fi transmitters are proposed to operate in the same frequency bands as the TV service receivers, electromagnetic interference (EMI) to the TV service receivers is a possibility. The National Association of Broadcasters (NAB) requested analysis support from Alion Science and Technology (Alion) to predict possible EMI from 6 GHz RLANs to ENG receiving systems.

The RLAN Wi-Fi transmitter routers expected to operate in the 6 GHz band will likely resemble the Wi-Fi routers currently operating in the 2 GHz and 5 GHz bands. At this stage, the critical data and information required to accurately assess the impact of the proposed RLAN Wi-Fi routers on 6 GHz ENG systems does not exist. However, sufficient RLAN Wi-Fi router data is available for the Wi-Fi transmitters operating in the 2 GHz and 5 GHz frequency bands that reasonable assumptions can be made as to technical and operational router RF characteristics such as the number of indoor and outdoor routers, router activity levels, and probability of router LOS with central receive site or TV van.

1.2 OBJECTIVE

The objective of this analysis was to identify and assess the likelihood and signal levels of EMI interactions from proposed 6 GHz RLAN Wi-Fi transmitters to the ENG A/V receivers currently operating in the 6 GHz band.

1.3 APPROACH

Alion performed analyses to investigate possible EMI to ENG receivers from deployments of 6 GHz RLAN Wi-Fi transmitters for selected representative scenarios. The NAB and Vislink Technologies identified the RF equipment, functions, and configurations typically used by broadcast operations in the 6.425-6.525 GHz and 6.875-7.125 GHz bands. The NAB also identified representative RF data links that may be susceptible to interference. San Diego, CA, Washington, DC, and Prince George's (PG) County, Maryland were chosen as representative sites for the analysis of ENG operations.

The Alion analysis approach was to: 1) characterize the ENG systems and deployment use cases, 2) characterize the RLAN systems, 3) model the deployments of the two systems according to representative use cases, and 4) predict the likelihood and signal levels of RLAN EMI to ENG receivers.

The analyses described in this report addressed potential EMI interactions between RLAN Wi-Fi transmitters and ENG receivers. The specific interactions analyzed were as follows:

- Deployments of RLAN Wi-Fi transmitters versus two ENG central receive sites located at Cowles Mountain near San Diego, CA and the Old Post Office building in Washington, DC.
- Deployments of RLAN Wi-Fi transmitters versus two ENG TV truck receivers located near the Washington, DC Mall and the Courthouse for PG County, Maryland.
- An interior scenario consisting of RLAN Wi-Fi transmitters versus an ENG receiver located in the Chamber of the US House of Representatives in Washington, DC.

2.0 SYSTEM CHARACTERISTICS

The system characteristics for the ENG and RLAN systems were collected and reviewed. ENG system characteristics were provided by NAB and Vislink. RLAN system characteristics were assembled from International Telecommunication Union (ITU) recommendations, band sharing studies, and the FCC NPRM and associated documents.

2.1 ENG SYSTEM CHARACTERISTICS

The ENG central receive site receiver characteristics are shown in Table 1.

Table 1. ENG central receive site receiver and antenna characteristics

Parameter	Data	Data Source
Cable/feed loss, dB	1.0	ITU-R M.1824-1[1] Vislink
Intermediate frequency (IF) bandwidth, MHz	20	Vislink
Noise figure, dB	4.0	ITU-R M.1824-1 (Ref. 1)
Receiver thermal noise, dBW	-127.0	Calculated
Antenna nomenclature	Vislink ProScan III	Vislink* data sheets 08/11/2009
Antenna type	Parabolic reflector	Vislink data sheets 08/11/2009
Antenna gain, dBi	36.0	Vislink antenna pattern
*Vislink RF equipment characteristics provided by Richard Miller of Vislink, 2 August – 10 Oct 2019		

The ProScan III antenna is a 1.4-meter reflector with a cosecant-squared elevation pattern typically used for ENG receive sites. The measured azimuth and elevation patterns of the ProScan III antenna are shown in Figure 1 and Figure 2, respectively. The antenna rotates a full 360 degrees in azimuth. Typically, these antennas are pointed at the horizon in the elevation plane. The cosecant-squared elevation pattern provides coverage at lower elevation angles. The insertion of a Low-Noise Block (LNB) downconverter near the antenna reduces the length of cable over which the worst losses occur and results in the relatively low cable/feed loss value presented in Table 1.

[1] Recommendation ITU-R M.1824-1, "System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies," International Telecommunications Union, Electronic Publication, Geneva, Switzerland, February 2015.

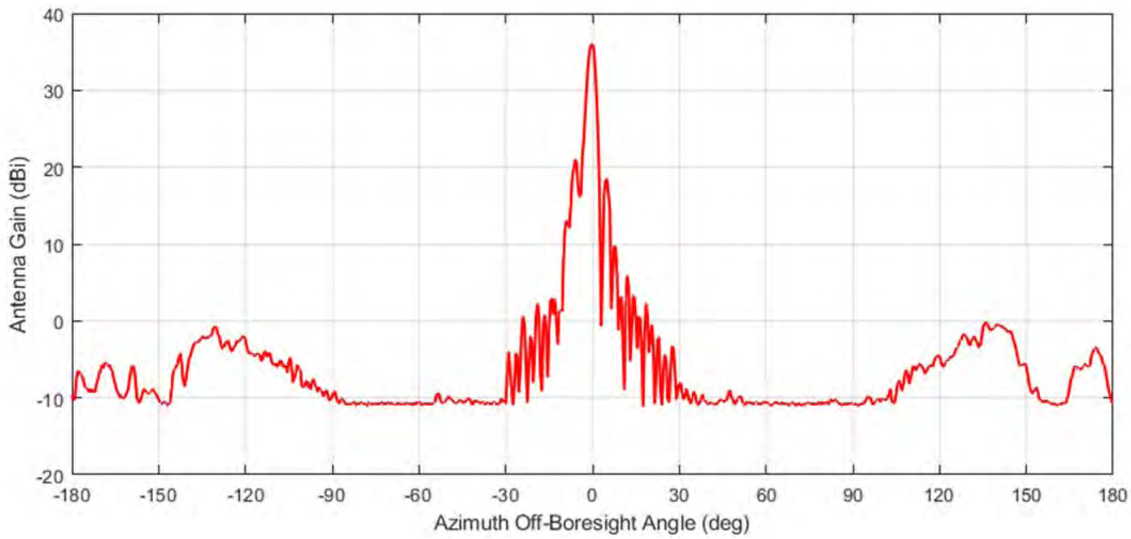

Figure 1. Measured ProScan III central receive site antenna azimuth pattern

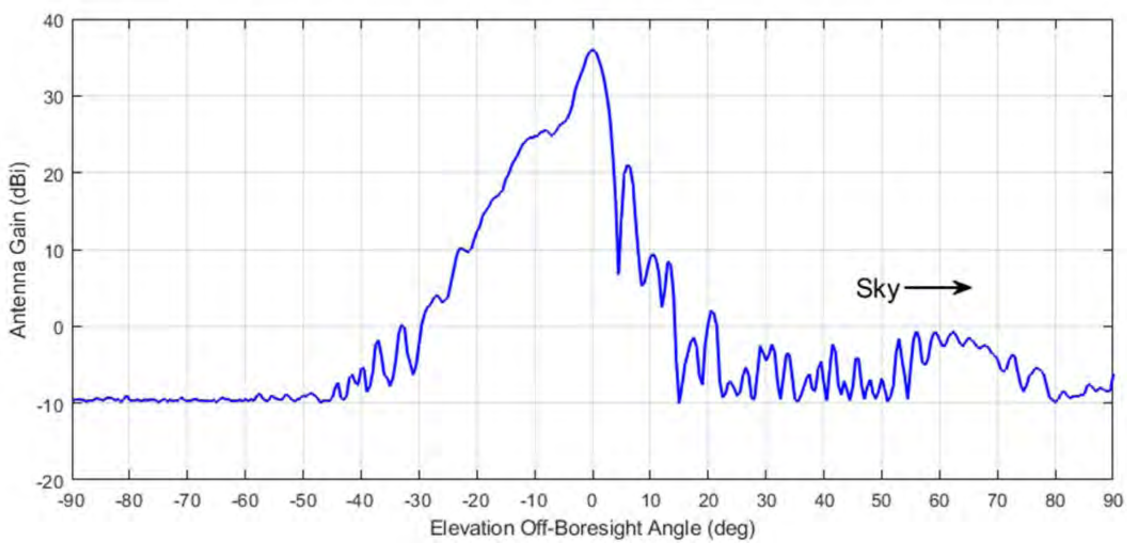

Figure 2. Measured ProScan III central receive site antenna elevation pattern

A three-dimensional (3D) model of the ProScan III antenna pattern, interpolated from the measured azimuth and elevation patterns, was used for the analysis and is presented below in Figure 3.

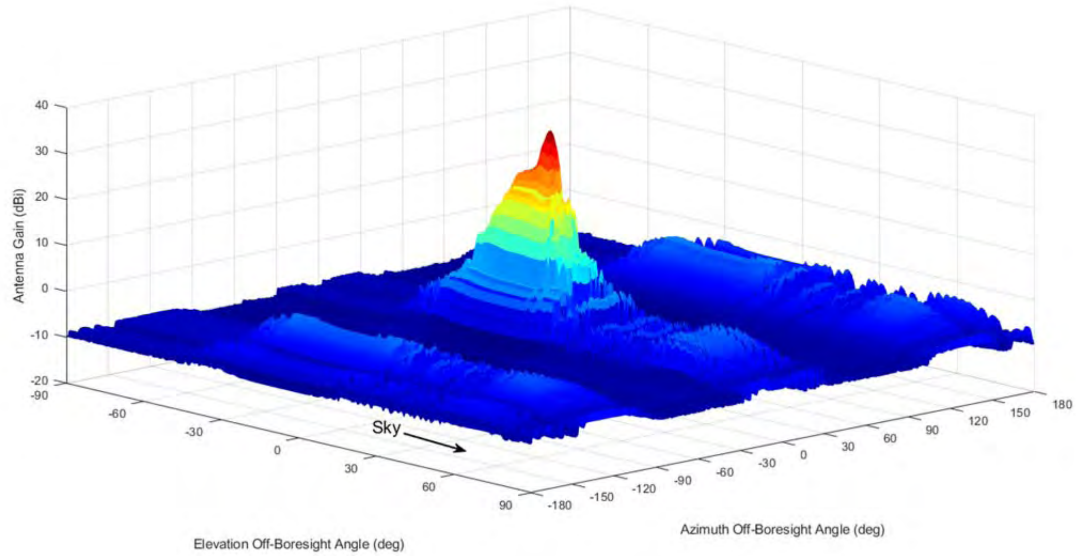

Figure 3. ProScan III central receive site antenna 3D model

The ENG truck receiver characteristics are shown in Table 2. The listed channel bandwidths are for Digital Video Broadcast –Terrestrial (DVB-T) and Link Modulation Standard Terrestrial (LMST), a proprietary Vislink modulation.

Table 2. ENG TV truck receiver characteristics

Parameter	Data	Data Source
Receiver nomenclature	Vislink L2174 diversity receiver	Vislink
Frequency, GHz	6.425-6.525, U-NII-6	National Telecommunications and Information Administration (NTIA) and FCC
Frequency, GHz	6.875-7.125, U-NII-8	NTIA and FCC
DVB-T Channel Bandwidths, MHz	6, 7, & 8	Vislink
LMST Channel Bandwidths, MHz	3,4,5,6,7,8,10,12 & 20	Vislink
Intermediate Frequency (IF) bandwidth, MHz	18, 20	Vislink
Receiver sensitivity, dBm	-101.44, -100.98	Vislink
Noise figure, dB	4.0	ITU-R M.1824-1 (Ref. 1)
Cable/feed loss, dB	1.0	Vislink and Ref. 1

The ENG truck receive antenna will be mounted to the truck roof or on a pneumatic mast, so the height variation is anywhere from 5 to 50 feet (1.5 m to 15 m) above ground level (AGL). For the analysis, results were generated for 1.5 m and 15 m antenna heights. The ENG truck receive antennas are typically omnidirectional (omni) collinear or sector antennas. For the analysis, a 3 dBi omnidirectional antenna (Vislink L3535) and a 12 dBi gain sector antenna (Vislink 9003561) were modeled, and the characteristics for these antennas are presented in Table 3 and Table 4, respectively.

Table 3. ENG truck omni collinear antenna characteristics

Parameter	Data	Data Source
Antenna nomenclature	Vislink L3535	Vislink
Frequency range, GHz	6.0-7.5	Vislink
Antenna type	Collinear array	Vislink
Mainbeam gain, dBi	3	Vislink
Antenna height, m	1.5 or 15	Vislink
Horizontal beamwidth, deg	360 (Omni)	Vislink
Vertical beamwidth, deg	76	Vislink
Polarization	Vertical	Vislink

Table 4. ENG truck sector antenna characteristics

Parameter	Data	Data Source
Antenna nomenclature	Vislink sector panel 9003561	Vislink
Frequency range, GHz	6.475-7.125	Vislink
Antenna type	Sector panel	Vislink
Mainbeam gain, dBi	12	Vislink
Antenna height, m	1.5 or 15	Vislink
Horizontal beamwidth, deg	120	Vislink
Vertical beamwidth, deg	19	Vislink
Polarization	Vertical	Vislink

Measured patterns for the ENG truck omni collinear and sector antennas were not available. The antennas were modeled using ITU recommendation ITU-R F.1336-4.[2] Figure 4, Figure 5, and Figure 6 show the modeled antenna gain patterns for the omni and sector antennas used in the analysis.

Finally, for the Chamber of the US House of Representatives deployment use case, the ENG receive antenna was assumed to be the Vislink L3535 omni antenna described in Table 3 above. The Vislink L3535 omni antenna was assumed to be located on the balcony railing in the corner of the front wall of the US House of Representatives. The modeled elevation gain pattern for the antenna is provided in Figure 4 below.

[2] ITU-R F.1336-4, "Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile services for use in sharing studies in the frequency range from 400 MHz to about 70 GHz," International Telecommunications Union, Electronic Publication, Geneva, Switzerland, February 2014.

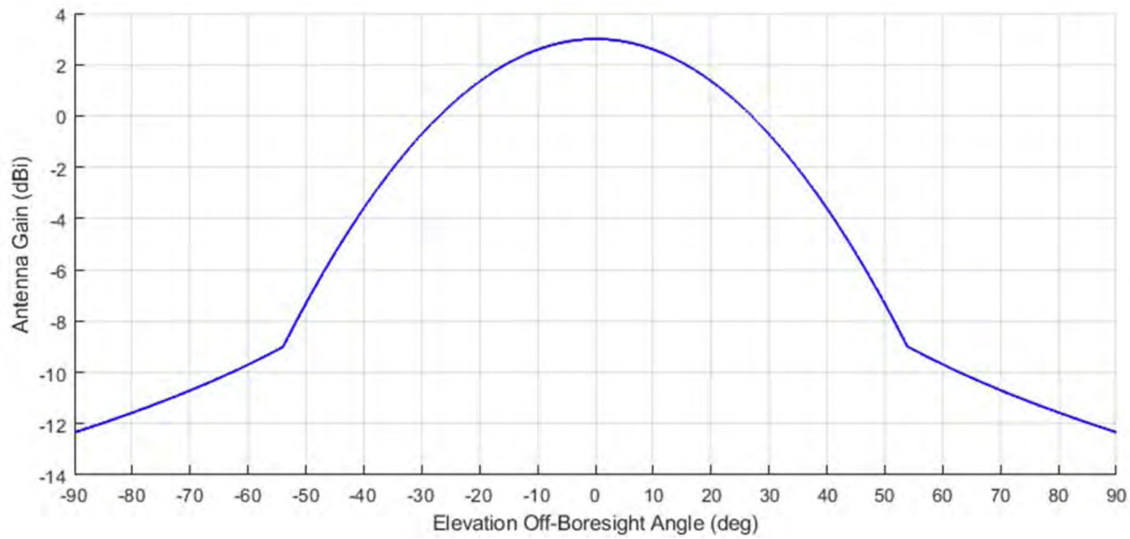

Figure 4. ENG truck omnidirectional antenna elevation pattern

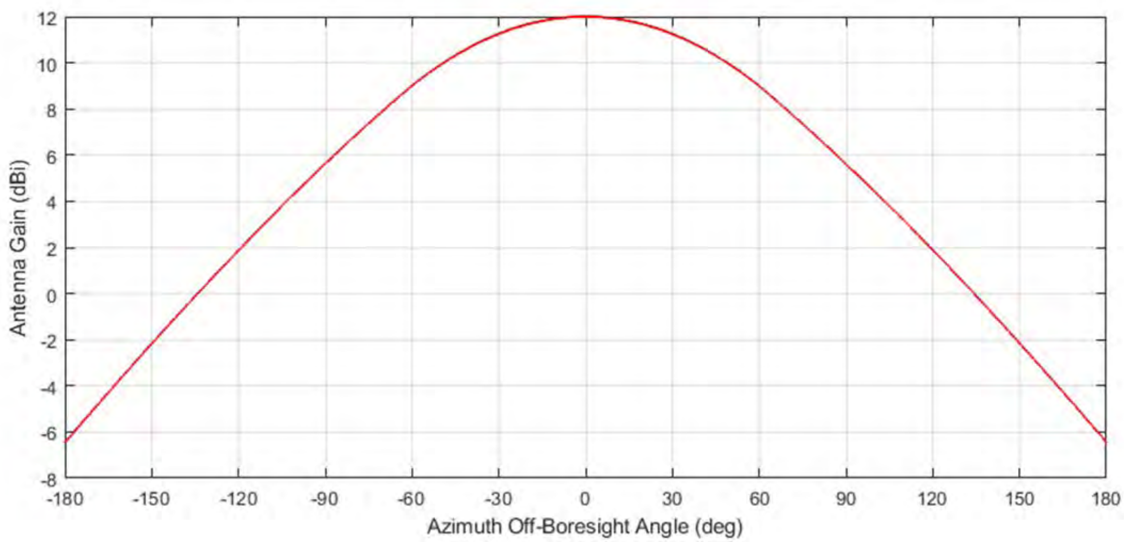

Figure 5. ENG truck sector antenna azimuth pattern

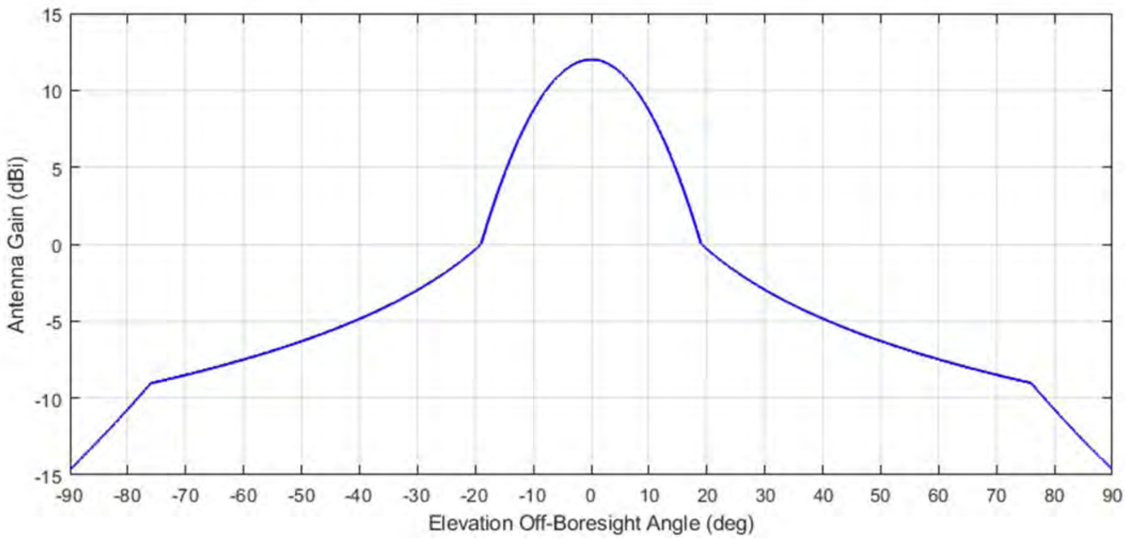

Figure 6. ENG truck sector antenna elevation pattern

2.2 RLAN SYSTEM CHARACTERISTICS

The characteristics for a hypothetical 6 GHz RLAN Wi-Fi transmitter and antenna were largely based upon RLAN characteristics found in several European 5 GHz sharing studies. In particular, RLAN transmit characteristics were obtained from the technical and operational characteristics in Annex 9 of ITU-R 5A/1065.[3] The indoor RLAN transmitter characteristics are shown in Table 5. The RLAN antenna elevation pattern was modeled using ITU recommendation ITU-R M.1652-1.[4] The antenna height was based on values taken from a sharing study in Annex 11[5] of ITU-R 5A/1065.

3 ITU-R 5A/1065 (Annex 9)-E, Annex 9 to Working Party 5A Chairman's Report, PRELIMINARY DRAFT "Technical characteristics and operational requirements of WAS/RLAN in the 5 GHz frequency range," ITU Electronic Publication, May 2019.

4 Recommendation ITU-R M.1652-1, "Dynamic frequency selection in wireless access systems including radio local area networks for the purpose of protecting the radiodetermination service in the 5 GHz band," ITU, Geneva, May 2011.

5 ITU-R 5A/1065 (Annex 11)-E, Annex 11 to Working Party 5A Chairman's Report, PRELIMINARY DRAFT, "Sharing and compatibility studies of WAS/RLAN in the 5 150-5 250 MHz frequency range," Electronic Publication, 13 May 2019.

Table 5. Indoor RLAN characteristics

Parameter	Data	Data Source
Equivalent Isotropically Radiated Power (EIRP), mW	25 – 200 (Power distribution shown in Table 8)	ITU-R 5A/1065 (Annex 9)-E (Ref. 3)
Transmit bandwidth, MHz	20, 40, 80, 160 (Bandwidth distribution shown in Table 9)	ITU-R 5A/1065 (Annex 9)-E (Ref. 3)
Antenna type	Omnidirectional in azimuth, elevation pattern as shown in Figure 7	ITU-R M.1652-1 (Ref. 4)
Mainbeam gain, dBi	0	ITU-R M.1652-1 (Ref 4)
Antenna height, m	1.5	ITU-R 5A/1065 (Annex 11)-E (Ref. 5)

The indoor RLAN antennas are omnidirectional in azimuth. Figure 7 shows the modeled indoor RLAN antenna elevation gain pattern used in the analysis. In the case of the indoor RLAN Wi-Fi antennas located in the ceiling of the Chamber of the US House of Representatives, the antenna gain pattern was modeled as omnidirectional in both azimuth and elevation.

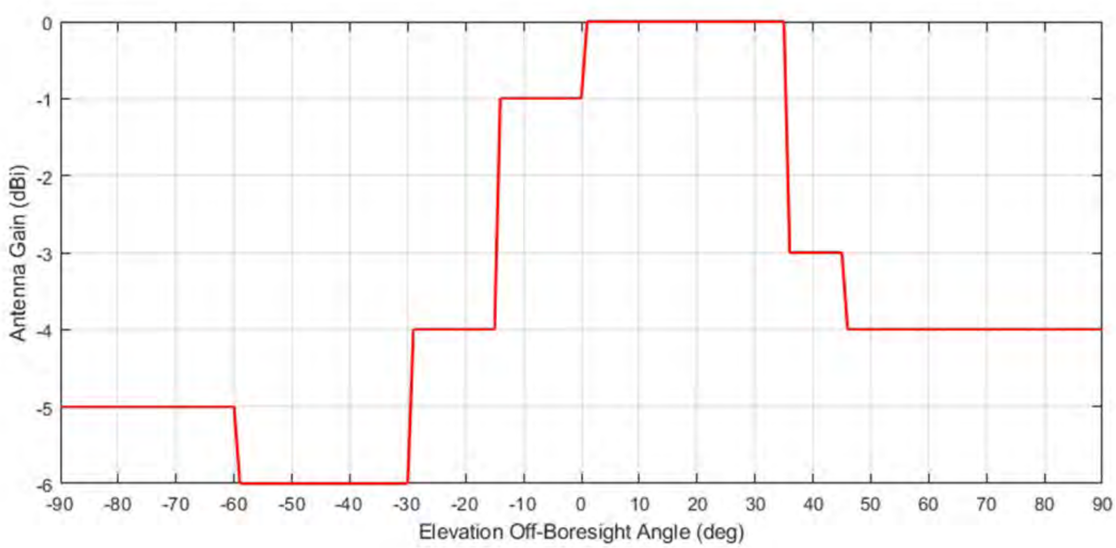

Figure 7. Indoor RLAN antenna elevation pattern (ITU-R M.1652-1)

The outdoor RLAN transmitter characteristics are shown in Table 6.

Table 6. Outdoor RLAN characteristics

Parameter	Data	Data Source
EIRP, mW	25 – 4,000 (Power distribution shown in Table 8)	ITU-R 5A/1065 (Annex 9)-E (Ref. 3)
Transmit bandwidth, MHz	20, 40, 80, 160 (Bandwidth distribution shown in Table 9)	ITU-R 5A/1065 (Annex 9)-E (Ref. 3)
Antenna type	Omnidirectional in azimuth*	ITU-R M.1652-1 (Ref. 4)
Mainbeam gain, dBi	0.0 (for EIRP≤1 W), 6.0 (for EIRP>1W)*	ITU-R M.1652-1 (Ref 4)
Antenna height, m	7.5	ITU-R 5A/1065 (Annex 11)-E (Ref. 5)
*Gain patterns; for RLAN transmitters ≤ 1 W see Figure 7, for RLAN transmitters > 1 W see Figure 8.		

ITU recommendation ITU-R M.1652-1 (Ref. 4) states that in order for most RLAN devices to achieve an EIRP of 1 watt (W), an antenna gain of 6 dBi is typically required. In this analysis, the ITU-R M.1652-1 (Ref. 4) antenna pattern for a 6 dBi omni was used for RLANs with an EIRP greater than 1 W. The elevation antenna pattern is shown in Figure 8. For RLANs with an EIRP less than or equal to 1 W, the ITU-R M.1652-1 (Ref. 4) antenna pattern for the indoor omni antenna was used, see Figure 7.

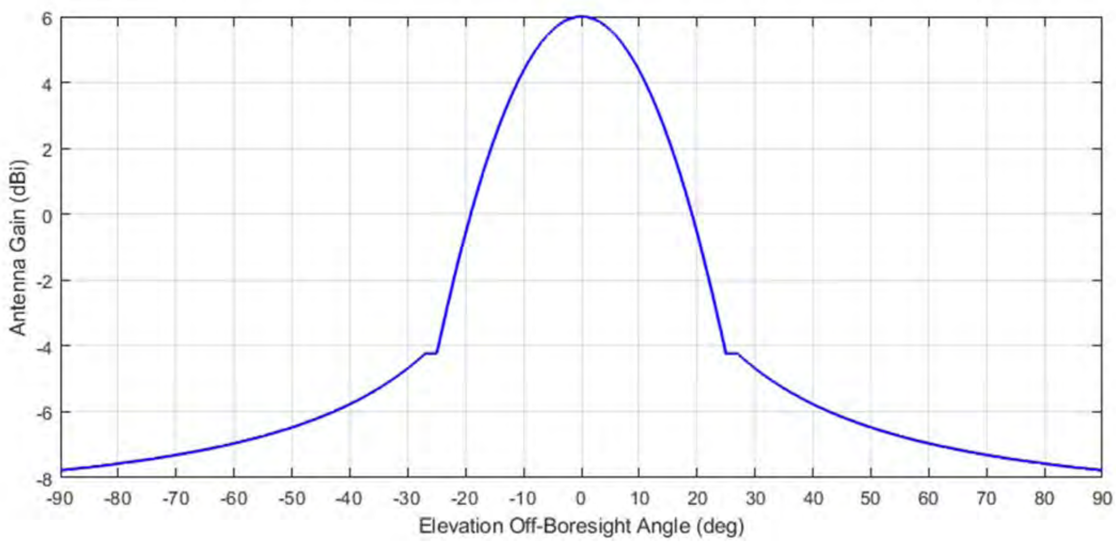

Figure 8. Outdoor RLAN 6 dBi gain antenna elevation pattern (ITU-R M.1652-1)

3.0 ANALYSIS

An analysis was performed to identify and assess the likelihood of EMI between proposed 6 GHz RLAN Wi-Fi transmitters and ENG A/V receivers operating in the 6 GHz band.

3.1 DEPLOYMENT USE CASES

Several representative ENG deployment use cases were investigated. The San Diego, CA and Washington, DC areas and their existing BAS and LTTS radio services were selected as representing typical outdoor RF broadcast environments into which 6 GHz RLAN Wi-Fi transmitters would be introduced. Two ENG central receive sites located at Cowles Mountain near San Diego, CA and the Old Post Office building in Washington, DC were chosen as receive sites to be investigated. Two commonly-used ENG truck locations near the Washington, DC Mall and the PG County, Maryland Courthouse were also selected. The RLAN environment in the vicinity of each of these outdoor ENG receiver sites was modeled. Finally, the Chamber of the US House of Representatives was chosen for the ENG interior receiver analysis. Table 7 lists the ENG receive site locations and antenna heights AGL.

Table 7. ENG receive sites

ENG receiver	Latitude	Longitude	Antenna Height, AGL, m
Cowles Mtn. ENG central receive site	32° 48' 49.30" N	117° 1' 56.43 W	50
Old DC Post Office ENG central receive site	38° 53' 38.86" N	77° 1' 40.94" W	90
ENG truck, C Street near DC Mall	38° 53' 36.76" N	77° 1' 3.23" W	1.5, 15
ENG truck, near PG County Courthouse	38° 48' 59.72" N	76° 45' 2.92" W	1.5, 15
ENG receiver	**Location**		**Antenna Height, m**
US House of Representatives, ENG interior	On the balcony railing front right corner		4.9

3.1.1 COWLES MOUNTAIN ENG CENTRAL RECEIVE SITE

The ENG central receive site antenna at Cowles Mountain near San Diego is located on a tower at 50 m AGL. The site is shown in Figure 9 (yellow marker).

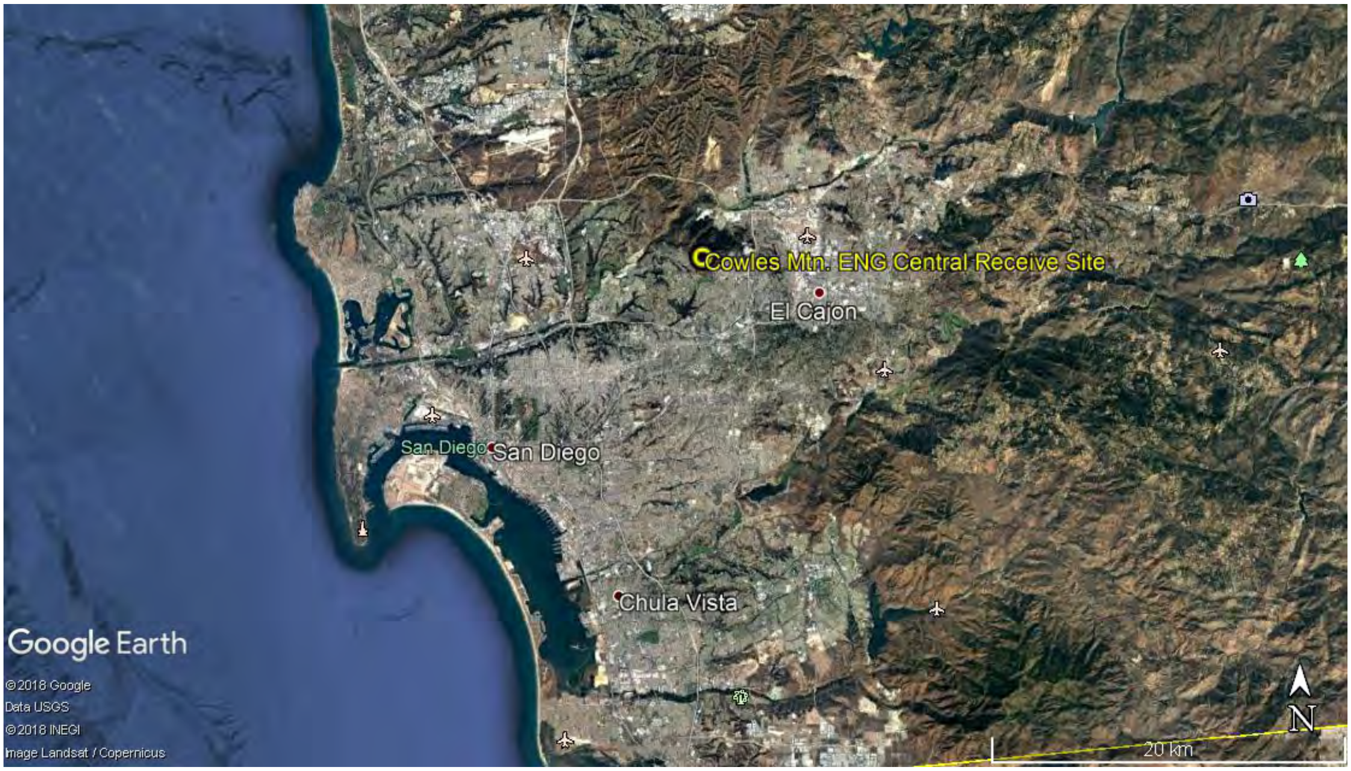

Figure 9. Cowles Mountain ENG central receive site (yellow marker)

3.1.2 WASHINGTON, DC, OLD POST OFFICE CENTRAL RECEIVE SITE

The ENG central receive site antenna at the Washington, DC Old Post Office building is located on a tower at 90 m AGL. The site is shown in Figure 10 (yellow marker).

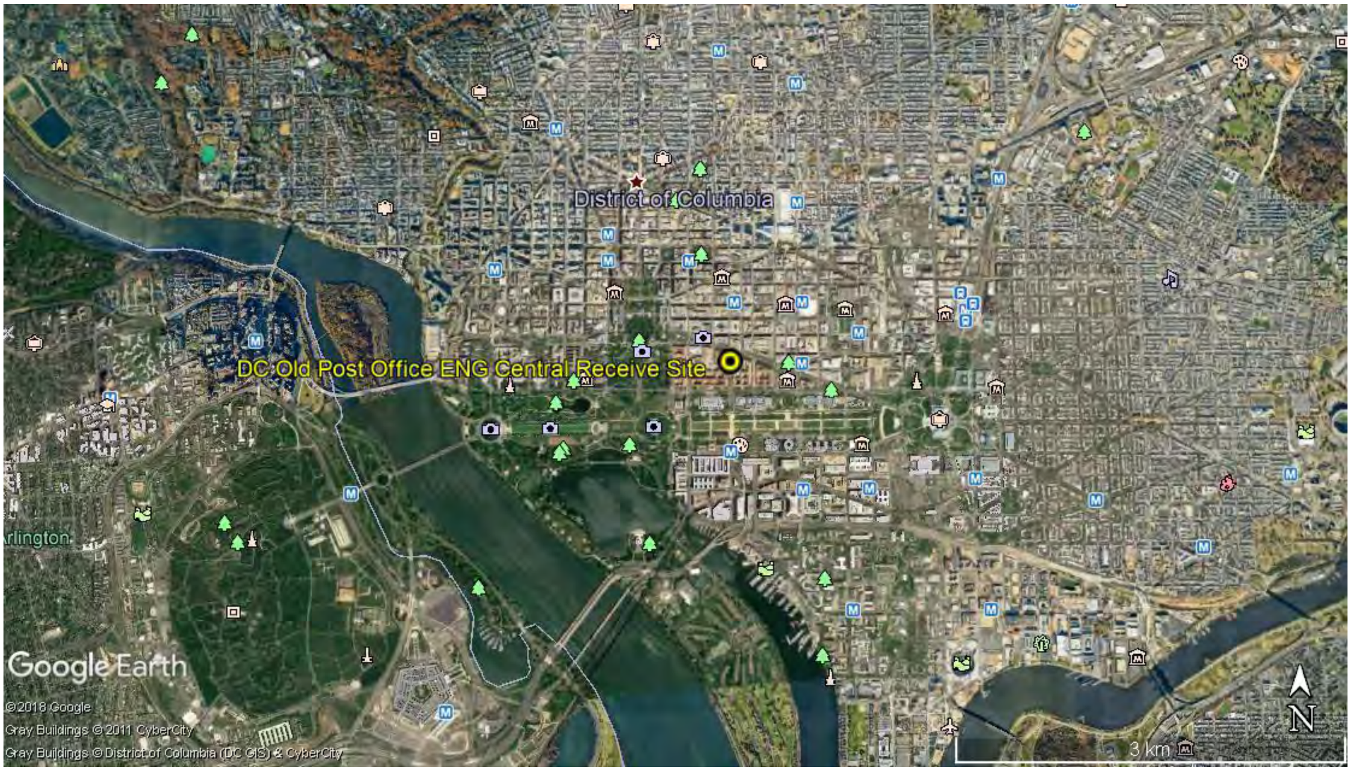

Figure 10. DC Old Post Office ENG central receive site (yellow marker)

3.1.3 ENG TRUCK NEAR WASHINGTON, DC, MALL

The ENG truck located near the Washington, DC Mall is shown in Figure 11 (yellow marker).

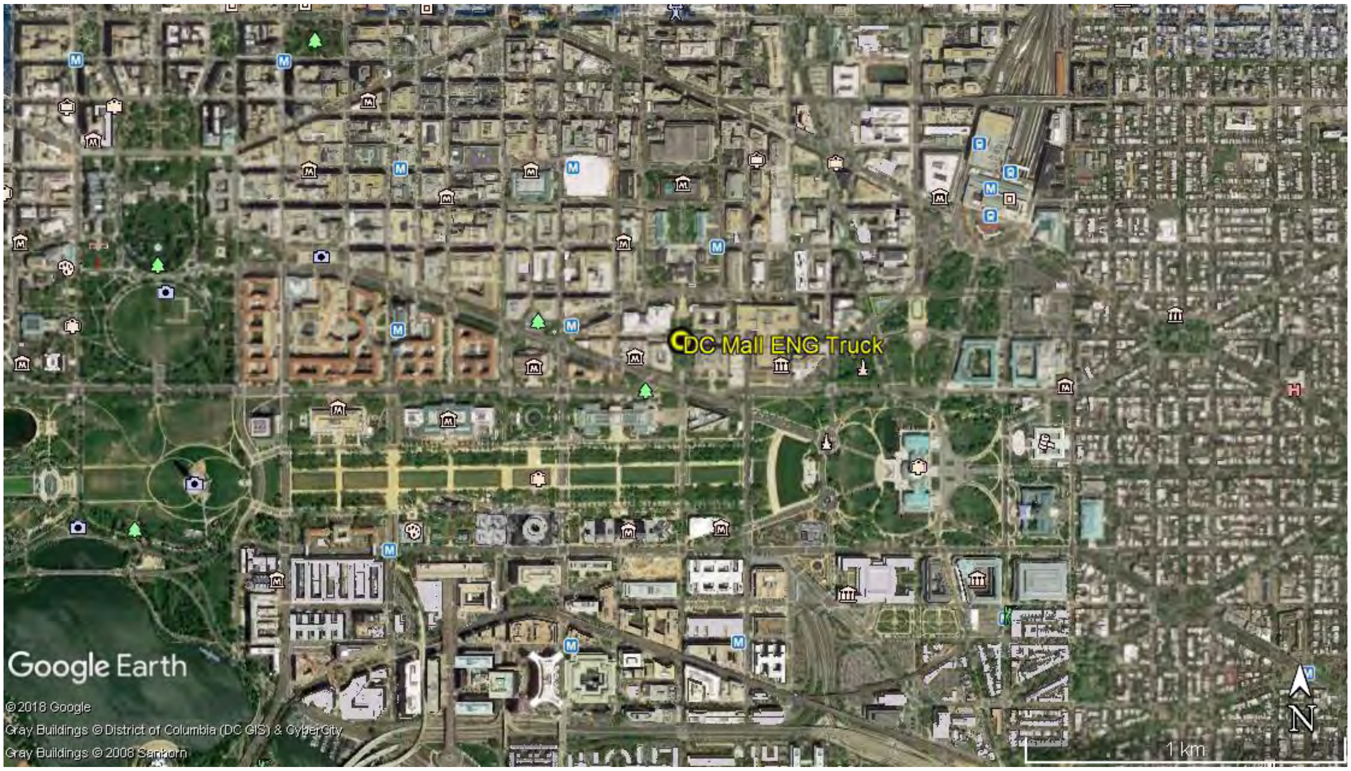

Figure 11. ENG truck near Washington, DC, Mall (yellow marker)

3.1.4 ENG TRUCK NEAR PRINCE GEORGE'S COUNTY COURTHOUSE

The ENG truck located near the PG County, Maryland Courthouse is shown in Figure 12 (yellow marker).

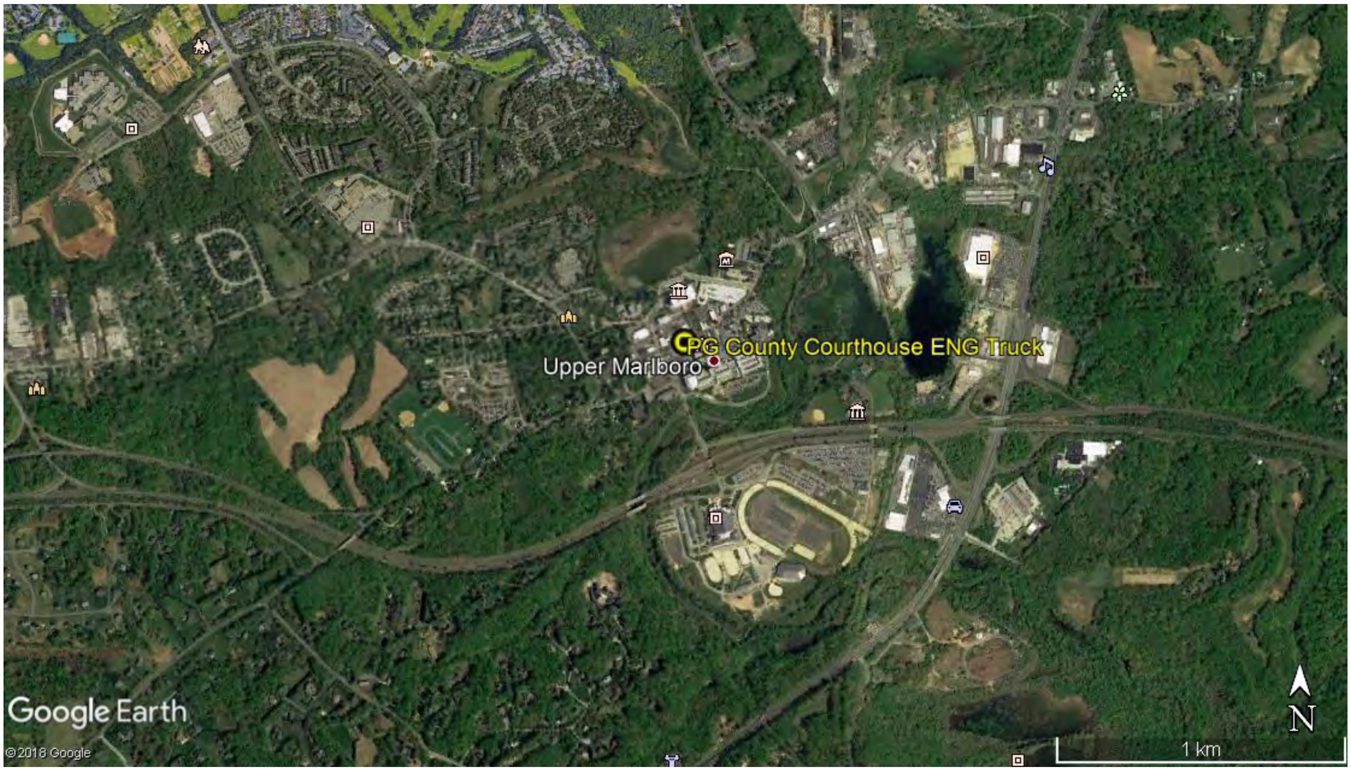

Figure 12. ENG truck near Prince George's County, MD, Courthouse (yellow marker)

3.1.5 ENG CENTRAL RECEIVE SITE AND ENG TRUCK RLAN ENVIRONMENT BASED ON CENSUS DATA

US Census Bureau data was used to establish the population densities in the neighborhoods surrounding the ENG central receive sites and ENG truck parking areas. The census data was extracted from the 2010 census and later population predictions undertaken in 2016 and 2018 that extrapolated from the initial 2010 population data. Census data is presented in the form of census tract maps which divide metropolitan areas, suburbs, and rural areas, into tracts that vary in size. Census tracts generally have a population size between 1,200 and 8,000 inhabitants, with an optimum size of 4,000 inhabitants. A census tract usually covers a contiguous area; however, the spatial size of census tracts varies widely depending on the density of settlement. The census data was used to determine the density of the deployment of RLANs in the vicinity of the ENG receive sites. Census data was not used for the ENG interior receiver analysis.

3.1.6 ENG RECEIVER WITHIN THE CHAMBER OF THE US HOUSE OF REPRESENTATIVES

The Chamber of the US House of Representatives was chosen for the ENG interior receiver analysis. The US House Chamber physical dimensions and ENG receive antenna location is shown in Figure 13.

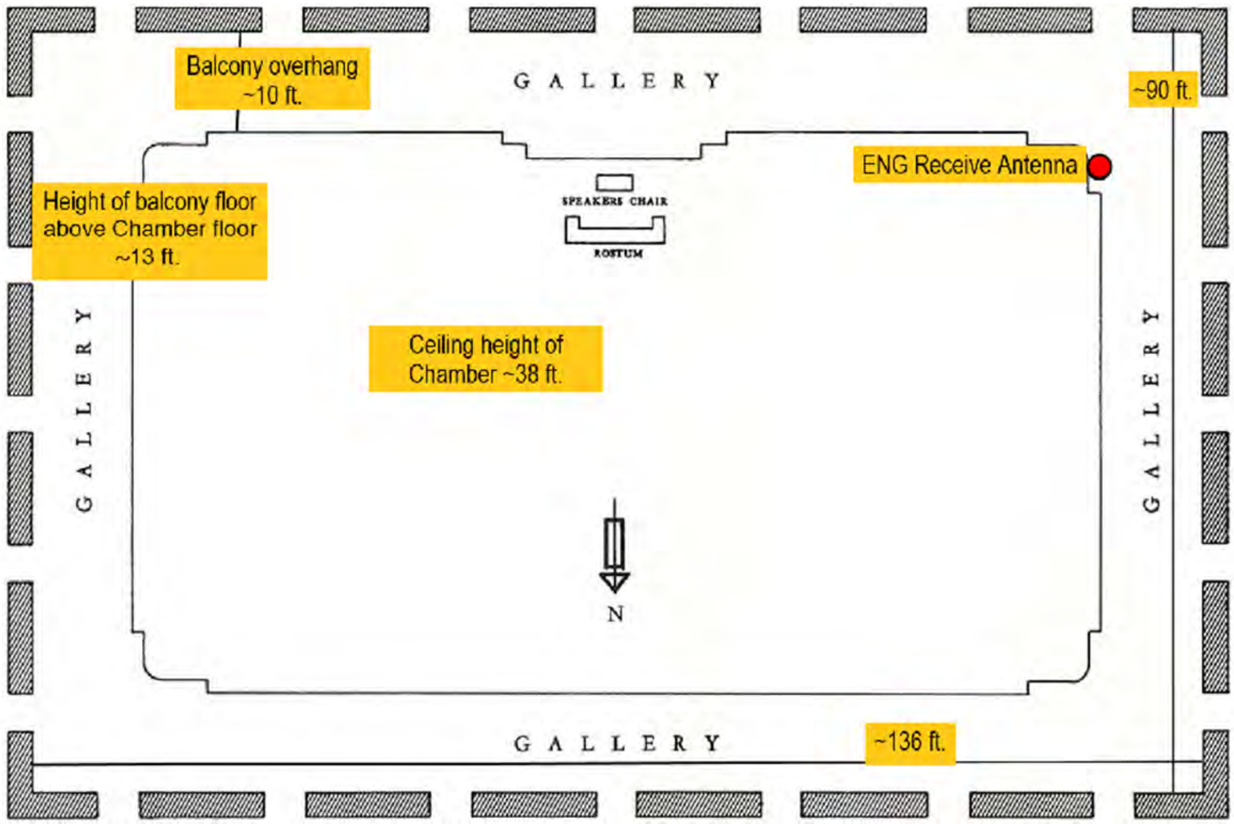

Figure 13. US House Chamber physical dimensions and ENG receive antenna location

The ENG interior receive antenna was located on the balcony railing in the southwest corner of the US House of Representatives. The height of the antenna on the railing was measured from the chamber floor. The position of the antenna is shown in Figure 14.

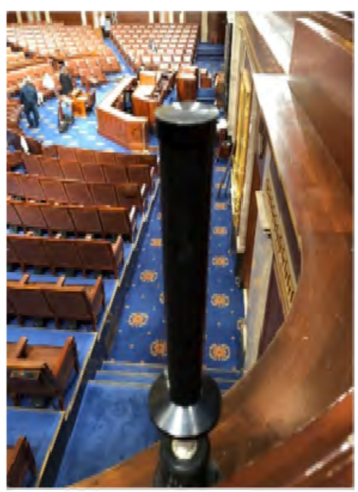

Figure 14. ENG interior receive antenna, balcony railing of the US House of Representatives

Figure 15 shows the exterior of the U.S. House Chamber with an overlay of the chamber dimensions. The red marker is the ENG receive antenna location.

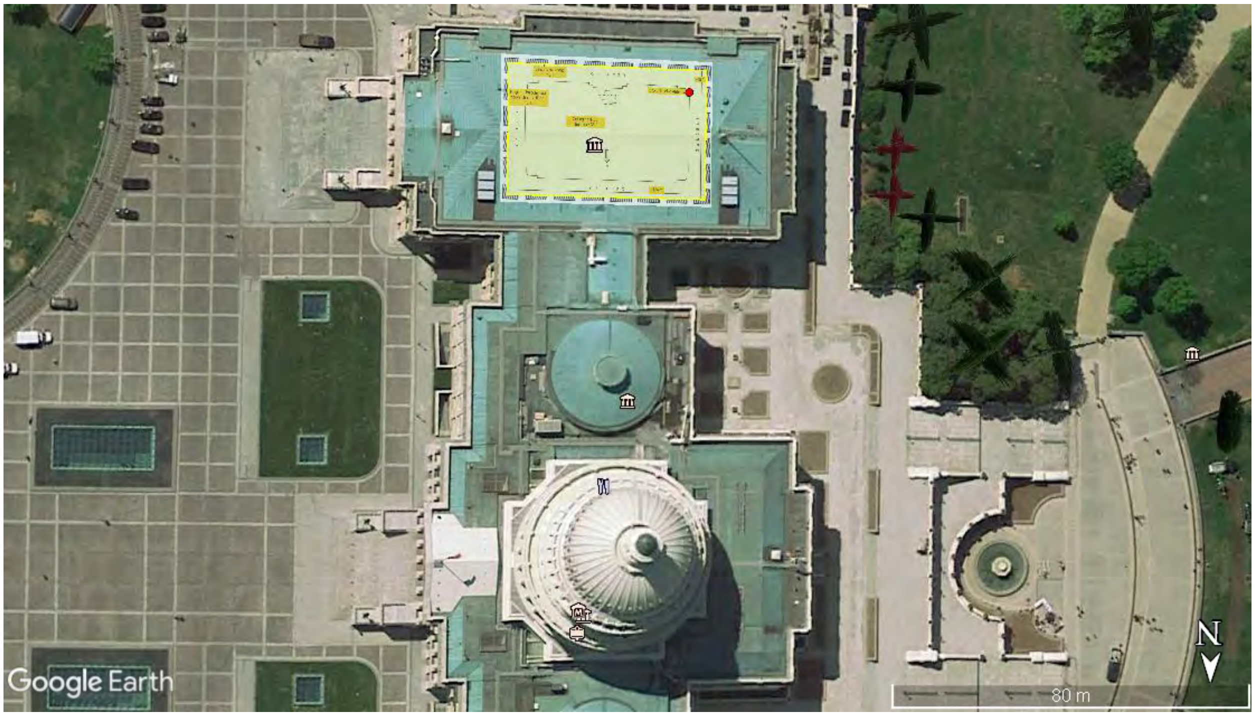

Figure 15. Aerial view of US Capitol (House Side) with overlay of Chamber dimensions (red marker = ENG receive antenna location)

The number of RLAN access points (APs) in the House Chamber was unavailable. According to the Office of the Chief Administrative Officer of the US House semiannual report (July - December 2014), the House Wi-Fi network was upgraded with over 1,000 wireless APs replaced throughout the House campus. For this analysis, the number of RLANs in the House Chamber was varied parametrically for 4, 20, and 50 RLANs. The RLANs were assumed to be installed on the ceiling of the Chamber.

Figure 16 shows the 4 RLAN locations (yellow markers). The red marker is the ENG receive antenna location.

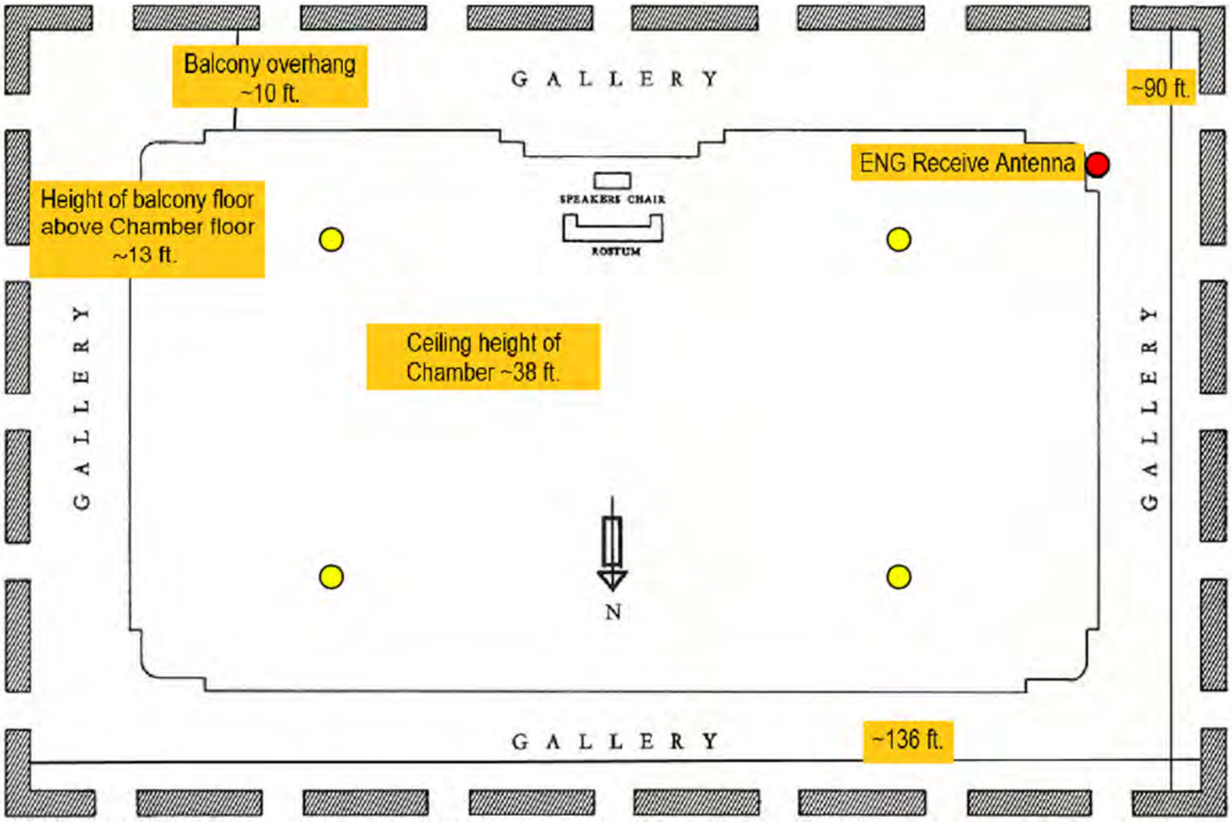

Figure 16. US House Chamber with 4 RLAN locations (yellow markers)

Figure 17 shows the 20 RLAN locations (yellow markers). The red marker is the ENG receive antenna location.

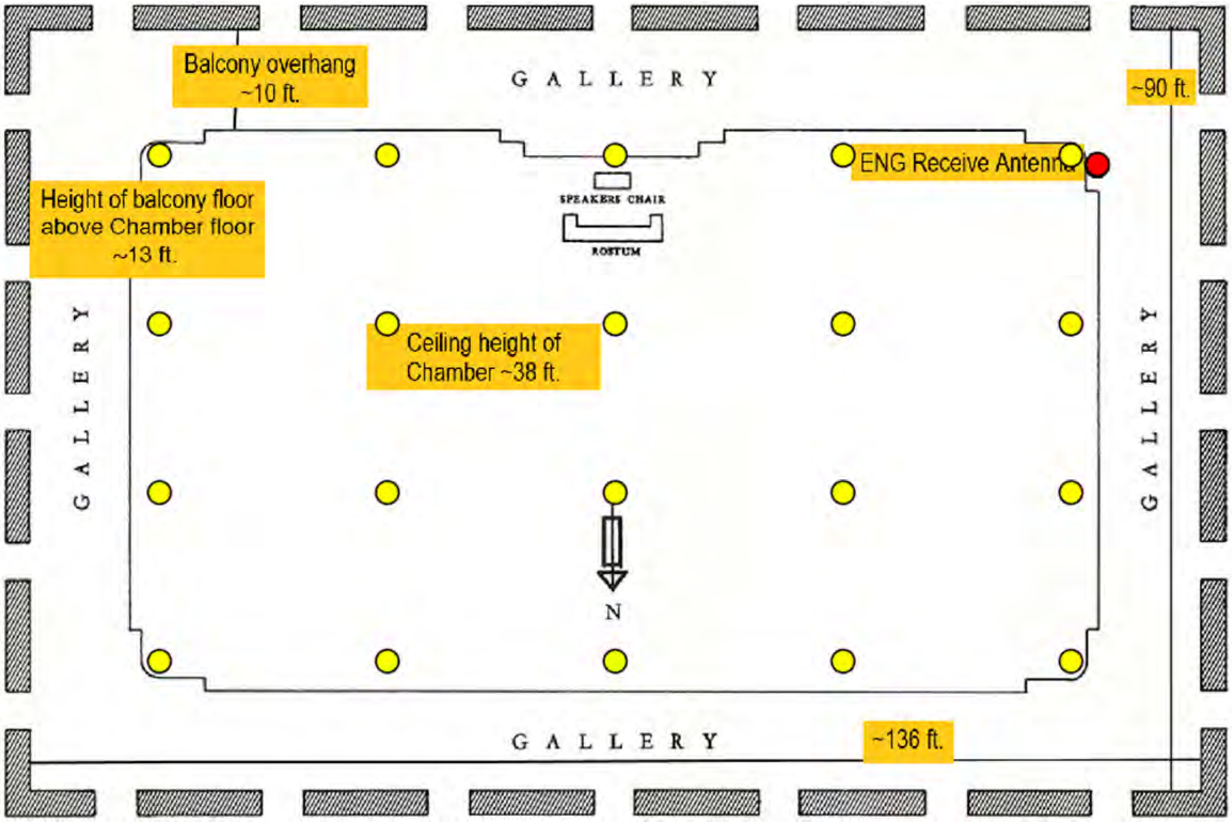

Figure 17. US House Chamber with 20 RLAN locations (yellow markers)

Figure 18 shows the 50 RLAN locations (yellow markers). The red marker is the ENG receive antenna location.

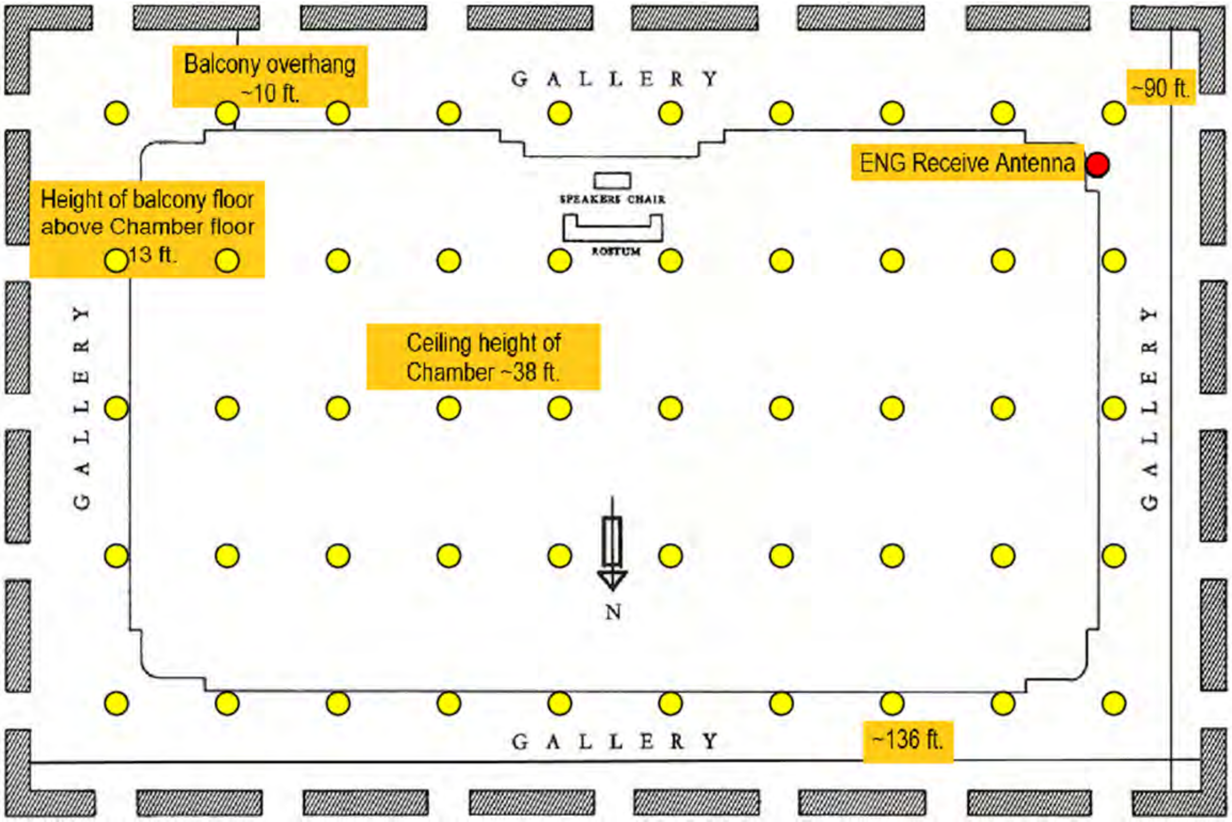

Figure 18. US House Chamber with overlay of 50 RLAN locations (yellow markers)

3.2 ENG CENTRAL RECEIVE SITE AND ENG TRUCK ANALYSIS ASSUMPTIONS

The objective of the analysis was to identify and assess the likelihood of RLAN EMI to ENG receivers. Aggregate RLAN EMI to ENG receivers was calculated for several deployment use cases using a Monte Carlo model. The Monte Carlo model employed iterative calculations with both random and defined variables to determine the likelihood of various interference interactions from the proposed 6 GHz RLAN Wi-Fi transmitters to the ENG receivers. In the interest of a balanced analysis, many of the decisions made regarding the technical and operational analysis assumptions favored the 'conservative' assumption. With respect to the issue of 6 GHz RLAN Wi-Fi transmit router compatibility with ENG receivers, a 'conservative' assumption is one that reduces or minimizes the effect of the RLAN Wi-Fi signals (*i.e.*, the analyses were not worst-case). Where possible, assumptions were supported with data from ITU recommendations. Many of the ITU recommendations referenced prior 5 GHz RLAN analyses. The Alion analysis assumptions follow:

- ENG central receive antenna:
  - The antenna rotates a full 360 degrees in azimuth.
  - The antenna is typically pointed at the horizon in the elevation plane. The cosecant-squared elevation pattern provides coverage at lower elevation angles.

- RLAN transmit routers were only included in the aggregate interference calculation if they had LOS to the ENG receiver.
  - Non-LOS (NLOS) RLANs were excluded from the aggregate interference calculation.
  - This is a conservative assumption since a RLAN that is NLOS due to terrain or clutter blockage (including blockage due to buildings) would still contribute an attenuated level of interference to the aggregate.
  - LOS links were determined using Light Detection and Ranging (LiDAR) data for each deployment use case.
  - The use of LiDAR data in the analysis is described in Section 3.4.
- Clutter and terrain effects were included.
  - The use of the LiDAR data incorporated the effects of terrain and clutter on the LOS link probabilities.
- A -10 dB Interference-to-Noise (I/N) long-term interference threshold was assumed as recommended for band sharing studies in ITU-R M.1824-1 (Ref. 1).
- Free-space propagation loss was used since all links considered were LOS.
- For LOS links to a building with an indoor RLAN, Building Entry Loss (BEL) was included in the RF propagation calculation for the link.
  - The BEL model used in the analysis is described in more detail in Section 3.5.
- Indoor RLANs were assigned a mix of 70% traditional and 30% thermally efficient buildings based upon an ITU working document on 2 GHz and 5 GHz RLAN analysis methodologies ITU-R 5A/650 (Annex 22)-E[6].
  - The characteristics of traditional and thermally efficient buildings are described in more detail in Section 3.5.

- The RLAN EIRP levels for indoor and outdoor RLANs were distributed. The EIRP distributions and proportions were taken from RLAN network characteristics described in ITU-R 5A/1065 (Annex 9)-E (Ref. 3) and are shown in Table 8.

Table 8. RLAN power distribution

Tx EIRP	4 W (directional)	4 W (omni)	1 W (directional)	1 W (omni)	200 mW (omni)	80 mW (omni)	50 mW (omni)	25 mW (omni)	all
Indoor RLAN	0%	0%	0%	0%	18%	25.6%	14.2%	36.9%	94.7%
Outdoor RLAN	0.025%	0.05%	0.075%	0.15%	0.95%	1.35%	0.75%	1.95%	5.3%

- RLANs were assumed to operate in 20, 40, 80, and 160 MHz bandwidth channels in compliance with Institute of Electrical and Electronics Engineers (IEEE) 802.11. The RLAN bandwidth

[6] ITU-R 5A/650 (Annex 22)-E, WORKING DRAFT "Use of aggregate RLAN measurements from airborne and terrestrial platforms to support studies under WRC-19 agenda item 1.16," Geneva, 16 November 2017.

distributions shown in Table 9 were obtained from the network characteristics in ITU-R 5A/1065 (Annex 9)-E) (Ref. 3). The distributions apply to both indoor and outdoor RLANs.

Table 9. RLAN bandwidth distribution

RLAN channel bandwidth	20 MHz	40 MHz	80 MHz	160 MHz
RLAN device percentage	10%	25%	50%	15%

- RLAN transmit channels were assumed to uniformly span the 2, 5, and 6 GHz bands. The probability of an RLAN transmit channel overlapping a 20 MHz ENG receive channel is shown in Table 10.

Table 10. Probability of RLAN channel overlapping ENG receive channel

RLAN transmit bandwidth	20 MHz	40 MHz	80 MHz	160 MHz
Probability of RLAN transmit channel overlapping 20 MHz ENG receive channel	0.012	0.023	0.050	0.111

- RLANs were only included in the aggregate interference calculation if the RLAN transmission channel overlapped the ENG receive channel. The on-tune rejection (OTR) as a function of RLAN transmit bandwidth is shown in Table 11.
  - This is a conservative assumption since RLANs tuned to channels adjacent to the ENG receive channel would contribute an attenuated level of interference (*e.g.*, interference from out-of-band emissions (OOBE)) to the aggregate.

Table 11. ENG receiver OTR

RLAN transmit bandwidth	20 MHz	40 MHz	80 MHz	160 MHz
ENG receiver OTR based on 20 MHz IF bandwidth	0 dB	3.0 dB	6.0 dB	9.0 dB

- Indoor RLAN height 1.5 m.
  - Indoor RLAN height distributions are heavily weighted toward the lower heights in urban, suburban, and rural environments. In fact, the single most common indoor RLAN transmit router height was found to be at the first-floor building height in the sharing study ITU-R 5A/1065 (Annex 11)-E (Ref. 5).
- Outdoor RLAN height 7.5 m.
  - A significant portion of public outdoor APs (hotspots and municipal networks) are strand or pole mounted at a height of approximately 7.5 meters, see ITU-R 5A/1065 (Annex 11)-E (Ref. 5).
- The assumption for the number of RLANs in the environment was one RLAN per inhabitant.

- This assumption was consistent with other sharing studies, including the RKF analysis "Frequency Sharing for Radio Local Area Networks in the 6 GHz Band."[7]
  - Based on the one per inhabitant assumption, US Census Bureau data was used to establish the RLAN densities.
- The proportion of indoor to outdoor RLANs was 94.7% to 5.3% according to ITU-R 5A/1065 (Annex 9)-E (Ref. 5).
- The proportion of all RLANs in a city that would be 6 GHz-capable was assumed to be 50% based upon market penetration projections used in other sharing studies such as the RKF analysis (Ref. 7).
- A 10% RLAN activity factor was assumed.
  - The activity factor describes how often, as a percentage of time, each RLAN transmitter is emitting a signal. If each RLAN transmit router is treated as an AP then the activity factor provides the number and density of APs emitting signal during a one hour period of particularly high usage in an urban, suburban or rural environment.
  - The conservative activity factor of 10% was chosen based upon a recent sharing study "Sharing and compatibility studies of WAS/RLAN in the 5 725-5 850 MHz frequency range"[8] although some studies have assumed activity factors three times as large.
  - The RKF analysis (Ref. 7) used a calculated device duty cycle of 0.44% for the Home Market device case. In terms of RLAN density, the Home Market case contributed the largest number of devices for urban, suburban, and rural environments. Although Alion does not endorse the 0.44% device duty cycle or the assumptions with which it was determined, the 0.44% activity factor was used in several Monte Carlo runs for comparison purposes.
- No polarization mismatch loss was assumed for the analysis.
- 10,000 iterations or snapshots were run using the Monte Carlo model for each deployment use case investigated.

3.3 AGGREGATE ANALYSIS MODEL

The aggregate interference analysis was conducted using a Monte Carlo simulation developed in MATLAB. MATLAB is a high-performance programming platform that provides mathematical computation, algorithm development, visualization, and analysis tools for engineering and science applications.

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[7] Pinney, T., "Frequency Sharing for Radio Local Area Networks in the 6 GHz Band" Ver. 3, RKF Engineering Solutions, LLC, 7500 Old Georgetown Road, Bethesda, MD, January 2018.

[8] ITU-R 5A/1065, Annex 12 to Working Party 5A Chairman's Report, PRELIMINARY DRAFT, "Sharing and compatibility studies of WAS/RLAN in the 5 725-5 850 MHz frequency range," Geneva, 13 May 2019.

An aggregate EMI analysis determines the cumulative effect of multiple interfering transmitters on a victim receiver. As such, the aggregate analysis offers a more complete evaluation of potential interference issues than a single-entry (*i.e.*, single-emitter) analysis. Single-entry EMI interactions sum to form the aggregate interference at the victim ENG receiver. Both aggregate and single-entry (maximum single-entry contribution, per snapshot) EMI results were collected from the Monte Carlo simulation and reported in the results section. Also, the percent of Monte Carlo snapshots for which the interference threshold was exceeded was determined.

The interfering signal level from a single RLAN to the ENG receiver was calculated using Equation 1.

$$P_I = P_T - L_{TS} + G_T - L_P - L_{BEL} + G_R - L_{RS} - FDR$$

(Equation 1)

where P_I = interference power at ENG receive antenna input, in dBW

P_T = RLAN transmit power, in dBW

L_{TS} = RLAN transmit system coupling losses, in dB

G_T = RLAN transmit antenna gain in direction of ENG receive antenna, in dBi

L_P = free-space propagation loss between RLAN & ENG antennas, in dB

L_{BEL} = Building entry loss, in dB (for outdoor RLANs, $L_{BEL} = 0$)

G_R = ENG receive antenna gain in direction of RLAN antenna, in dBi

L_{RS} = Receive system coupling losses, in dB

FDR[9] = frequency-dependent rejection, in dB

The ENG receiver noise was calculated using Equation 2.

$$N_R = 10 * \log_{10}(k * T * B) + N_F$$

(Equation 2)

where N_R = Receiver noise power, in dBW

T = Ambient temperature, 290 degrees Kelvin (K)

k = Boltzmann's constant, $1.38 * 10^{-23}$ J/K

B = Receiver bandwidth, in Hz

N_F = Receiver noise figure, in dB

The single-entry interference contributions were then summed to form the aggregate received interference at the ENG receiver. The numerical (not dB) I/N ratio of the aggregate received interference power at the ENG receiver and the ENG receiver noise was then calculated by summing the individual

[9] For the ENG receive site and ENG truck analysis only on-tune interference was considered, therefore FDR = On-Tune Rejection (OTR). For the ENG interior analysis, both on-tune and adjacent channel interference was considered, therefore FDR = OTR + Off-Frequency Rejection (OFR).

P_I interference power contributions in Watts, dividing by the receiver noise power in Watts, and taking 10 times the $\log_{10}$ of the result. This aggregate I/N ratio was compared to the I/N threshold criterion, I/N_{TH} = -10 dB, as recommended in the sharing studies of ITU-R M.1824-1 (Ref. 1). Interference was declared when the aggregate I/N exceeded I/N_{TH}. The analysis also determined the percent of Monte Carlo snapshots for which the interference threshold was exceeded.

3.4 LOS LINK DETERMINATION USING LiDAR

LiDAR is a remote sensing method that uses laser pulses to measure all the various ranges possible in a scan of a small segment of the Earth's surface. A LiDAR instrument, or measurement device, consists of a laser, a scanner, and a specialized GPS receiver.

By combining census tract data with LiDAR data Alion achieved a relatively high degree of accuracy when determining the probability that a RLAN Wi-Fi transmitter in a particular census tract was LOS or NLOS to an ENG receiver. Five-meter resolution LiDAR data, procured from the Army Geospatial Center (AGC), was used to determine the LOS links for the census tracts and the varying number of RLAN Wi-Fi transmitters within the tracts.

The probability of the RLAN transmitters in a particular census tract having LOS links to ENG receivers was determined as a function of RLAN height. Statistics were developed for the RLAN LOS probabilities for each census tract. The indoor RLANs were assumed to be at a height of 1.5 meters on the first floors of buildings. The outdoor RLANS were assumed to be strand or pole mounted at a height of 7.5 meters. A grid of points was distributed across the census tracts, at each of the two RLAN heights. The "Quick Terrain Modeler"[10] software was used to determine which grid points were LOS to the ENG receive antenna. "Quick Terrain Modeler" (Ref. 10) is a vector analysis software package designed to facilitate LOS determinations using LiDAR data.

For each census tract, the probability of a LOS link was calculated using the LOS/NLOS data for each grid point within the tract. The use of the LiDAR data incorporated the effects of terrain and clutter on the LOS link probabilities. These LOS statistics were incorporated into the Monte Carlo model. Based on the LOS link probabilities, RLAN Wi-Fi transmitters were only considered if they had LOS to the ENG receiver. NLOS RLAN Wi-Fi transmitters were excluded from the aggregate interference calculation. This is a conservative assumption since an RLAN Wi-Fi transmit router that is NLOS due to terrain or clutter blockage will contribute an attenuated (but non-zero) level of interference to the aggregate. The LOS determination for an indoor RLAN assumed that the building face was LOS to the ENG receiver. Propagation path loss between the RLAN Wi-Fi transmitter and the ENG receiver was

[10] "Quick Terrain Modeler, Version 8 User Manual," LiDAR Exploitation Software by Applied Imagery, Applied Imagery LLC, 2014

calculated. For indoor RLANs, an additional BEL was added to the propagation path based on building type as discussed below.

3.5 BUILDING ENTRY LOSS

For LOS links to a building with an indoor RLAN, BEL was included in the RF propagation calculation for the link. The data in ITU-R P.2109-1 “Prediction of Building Entry Loss”[11] was used in the analysis. Indoor RLANs were categorized as within traditional or thermally-efficient buildings. ITU experimental results compiled in ITU-R P.2346[12] were used to select the particular building losses that were applicable for each RLAN Wi-Fi transmit router. Significantly larger BEL values were assigned to modern, ‘thermally efficient’ buildings (*e.g.*, metallized glass, foil-backed panels, etc.) than to the older ‘traditional’ buildings that usually lack those materials with high RF attenuation. The BEL model provides predictions for these two cases. This classification of buildings, as being either ‘thermally-efficient’ or ‘traditional,’ refers purely to the thermal efficiency of the construction materials. Assumptions should not be based solely on year of construction, house design (single or multi-floor), or building method. For BEL, it is important to consider the thermal efficiency of the complete building (or the overall thermal efficiency). Thermal transmittance, commonly referred as U-value, provides a quantifiable description of thermal efficiency. Low U-values represent high thermal efficiency. The presence of metallized glass windows, insulated cavity walls, thick reinforced concrete and metal foil back-cladding were considered indicators in ITU-R P.2109-1 (Ref. 11) of a thermally-efficient building.

For the analysis, 30% of the indoor RLANs were assumed to be in thermally-efficient buildings and 70% in traditional buildings in accordance with the assumptions for RLAN studies described in Annex 22 of ITU-R 5A/650, (Ref. 6). Figure 19 shows the ITU BEL model for traditional and thermally efficient buildings at 6.425 GHz and at a horizontal incidence.

[11] ITU-R P.2109-1, “Prediction of building entry loss,” Electronic Publication, Geneva, August 2019.
[12] ITU-R P.2346, “Compilation of measurement data relating to building entry loss,” Electronic Publication, Geneva, March 2017.

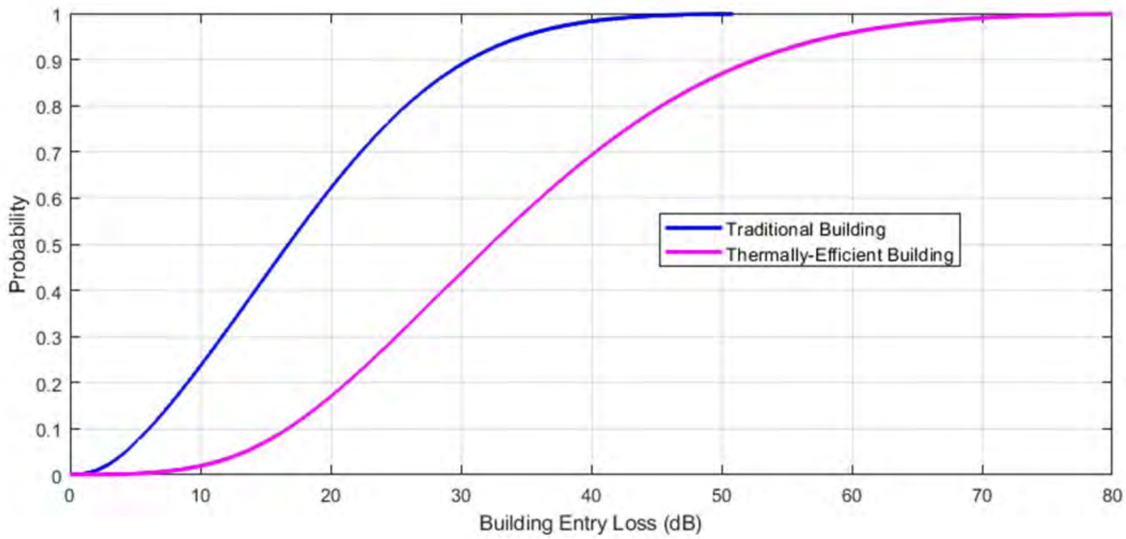

Figure 19. Building entry loss predicted at normal incidence (6.425 GHz)

3.6 ENG CENTRAL RECEIVE SITES

This section provides additional information on the modeling of the ENG receive sites using LiDAR data. Those regions in green in the LiDAR 'map' of Figure 20 show the hills, ridges, rises, plateaus and other terrain features around San Diego where an indoor RLAN Wi-Fi transmitter (1.5-meter height) would have LOS to the ENG central receive site on Cowles Mountain. The regions in red are the buildings, valleys, canyons, and forested sections where an indoor RLAN Wi-Fi transmitter would be blocked from the ENG central receive site on Cowles Mountain. Figure 21 presents the LOS and NLOS regions for outdoor RLAN Wi-Fi transmit routers (7.5-meter height) to the ENG central receive site on Cowles Mountain. Likewise, LOS regions are shown in green, NLOS regions are shown in red.

The LiDAR data was employed in the LOS determinations used in analyses undertaken for Washington DC and PG County as well as San Diego. However the following LOS and NLOS LiDAR region maps were only generated for San Diego in order to show the procedure followed. It was not deemed necessary to generate the LiDAR coverage plots for every deployment scenario. The LOS probability maps show the results of the LiDAR coverage plots.

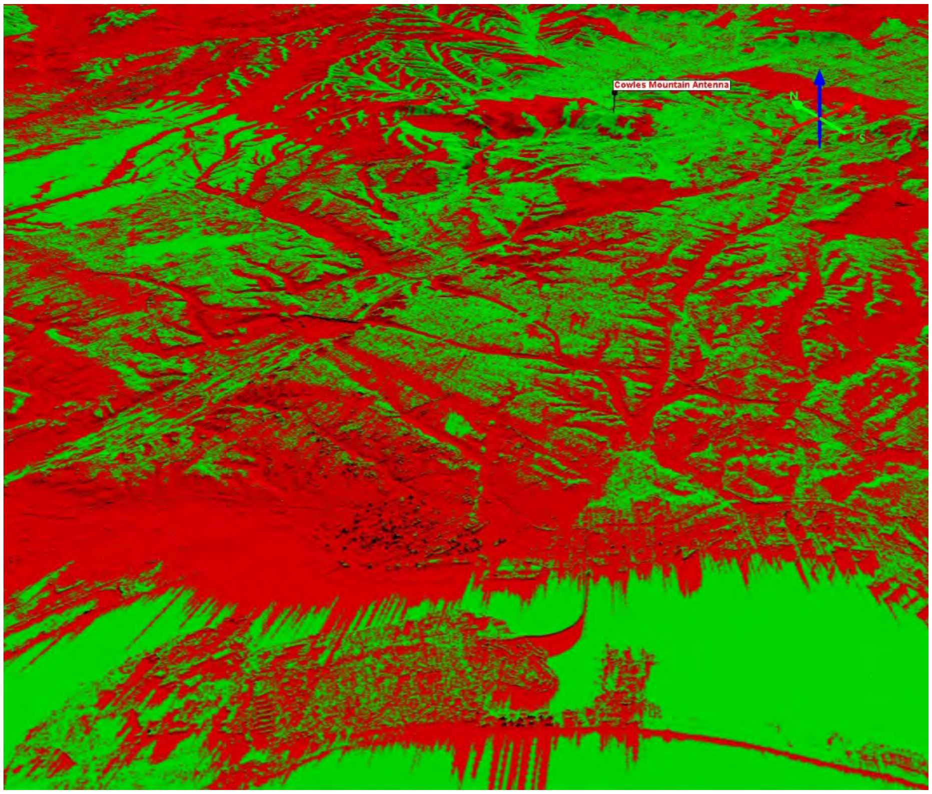

Figure 20. Cowles Mountain ENG receiver LiDAR LOS regions for indoor RLANs (1.5 m height) (green regions LOS, red regions NLOS)

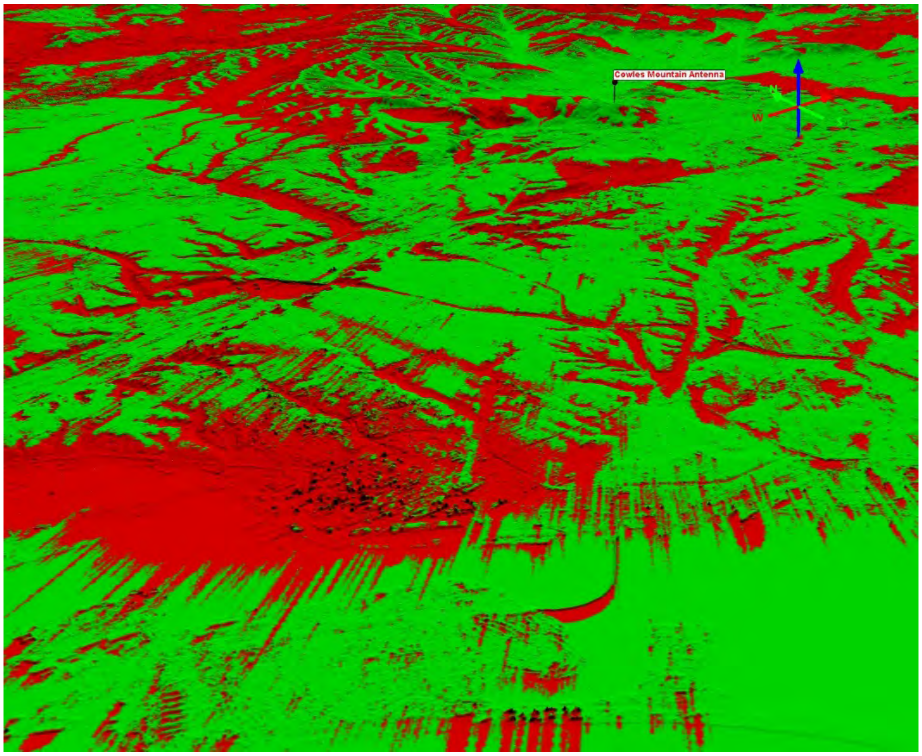

Figure 21. Cowles Mountain ENG receiver LiDAR LOS regions for outdoor RLANs (7.5 m height) (green regions LOS, red regions NLOS)

The following plots show the probability of LOS from RLANs in each census tract to the ENG central receive sites near San Diego and Washington, DC. Figure 22 and Figure 23 show the Cowles Mountain ENG central receive site probability of LOS for indoor and outdoor RLANs, respectively. The ENG receive sites are shown as blue markers.

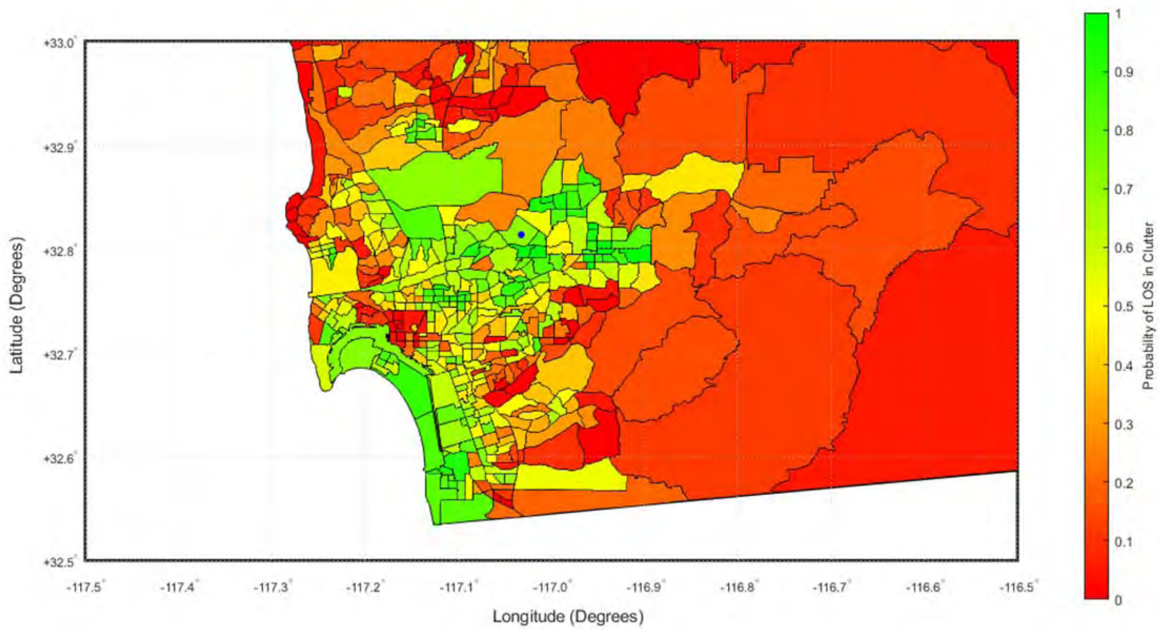

Figure 22. LOS Probability per census tract (Indoor RLANs) to ENG central receive site at Cowles Mountain

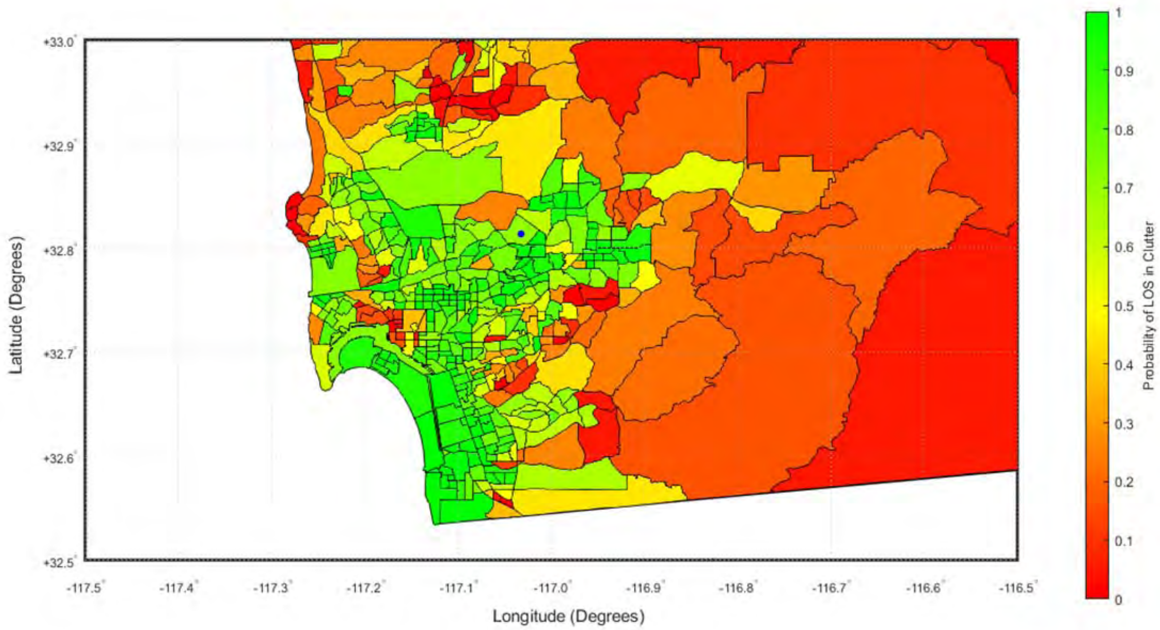

Figure 23. LOS Probability per census tract (Outdoor RLANs) to ENG central receive site at Cowles Mountain

Figure 24 shows the LOS probability per census tract for indoor RLANs (1.5-meter height) to the ENG central receive site on the Old Post Office in Washington, DC. Figure 25 shows an expanded view.

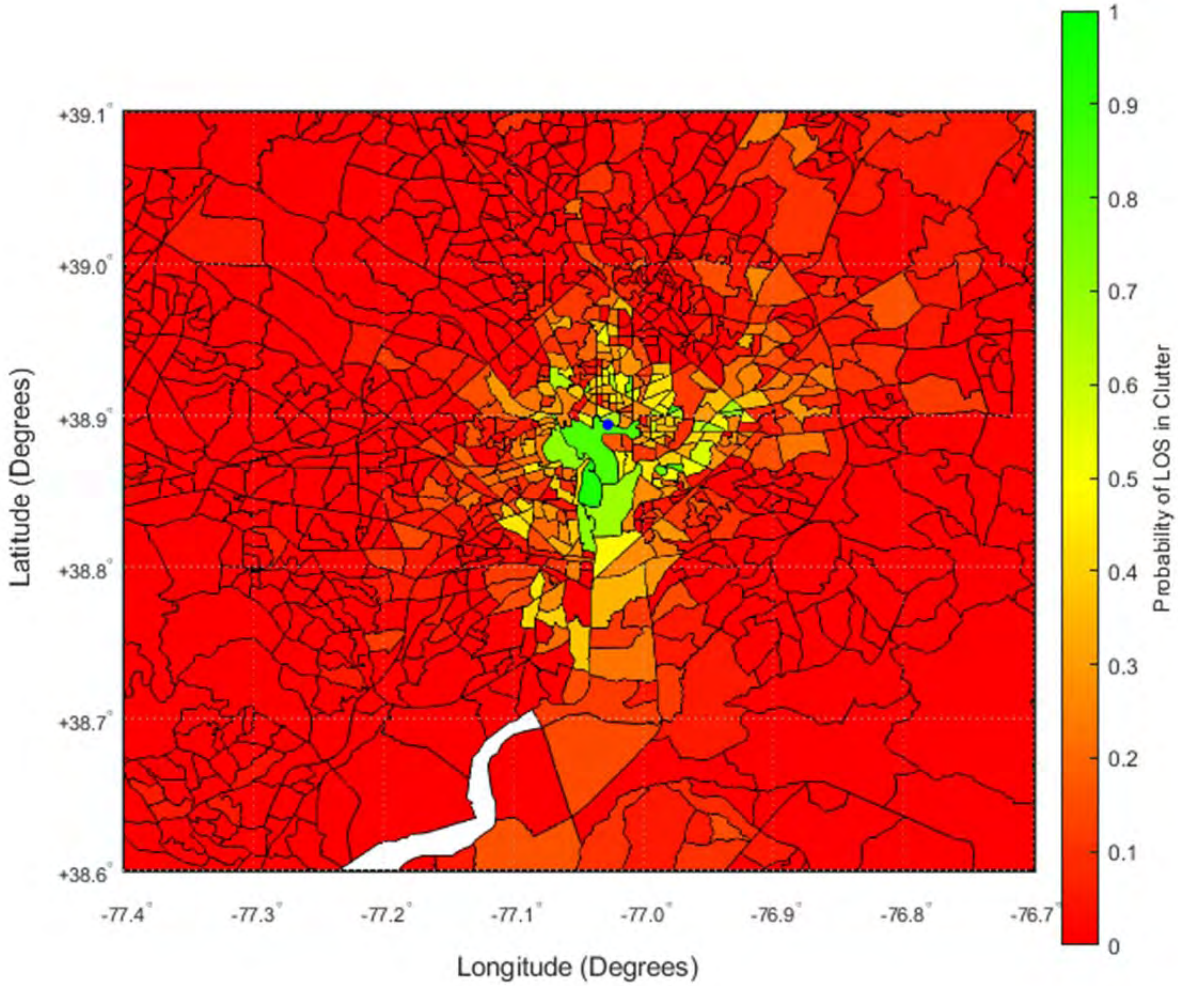

Figure 24. LOS Probability per census tract (Indoor RLANs) to ENG central receive site at the Old Post Office

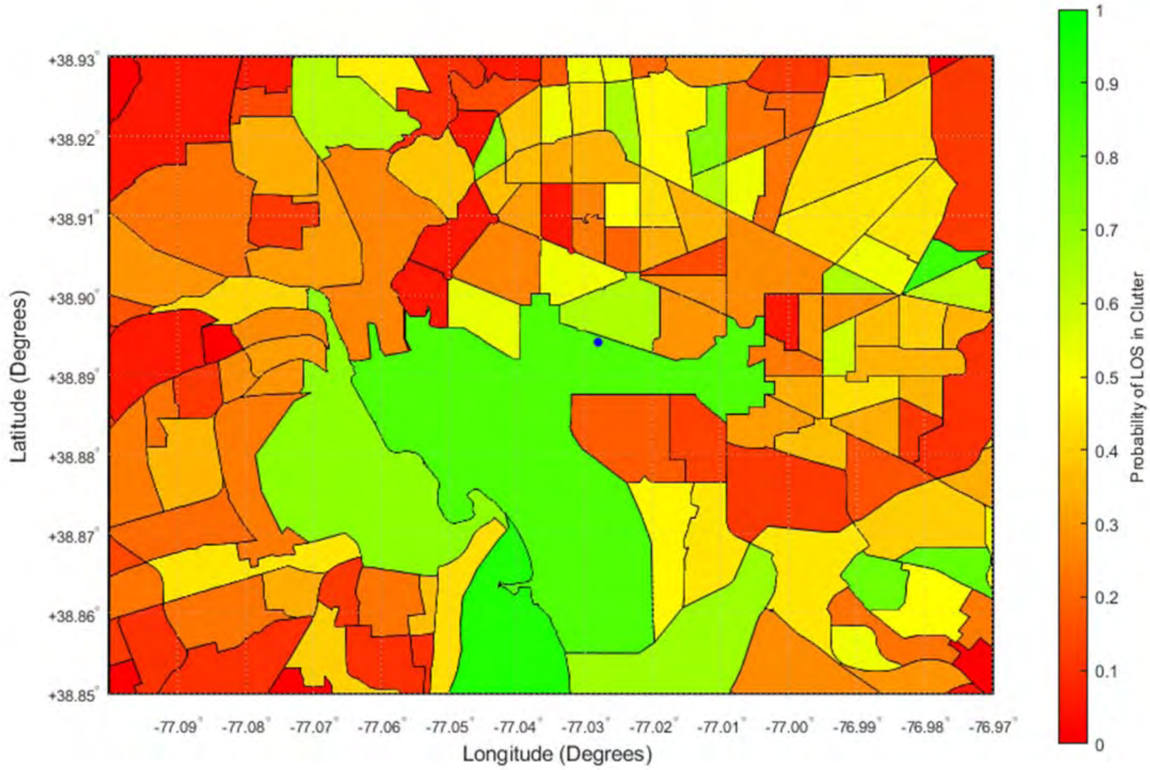

Figure 25. LOS Probability per census tract (Indoor RLANs) to ENG central receive site at the Old Post Office (expanded view)

Figure 26 shows the LOS probability per census tract for outdoor RLANs (7.5-meter height) to the ENG central receive site on the Old Post Office in Washington, DC. Figure 27 shows an expanded view.

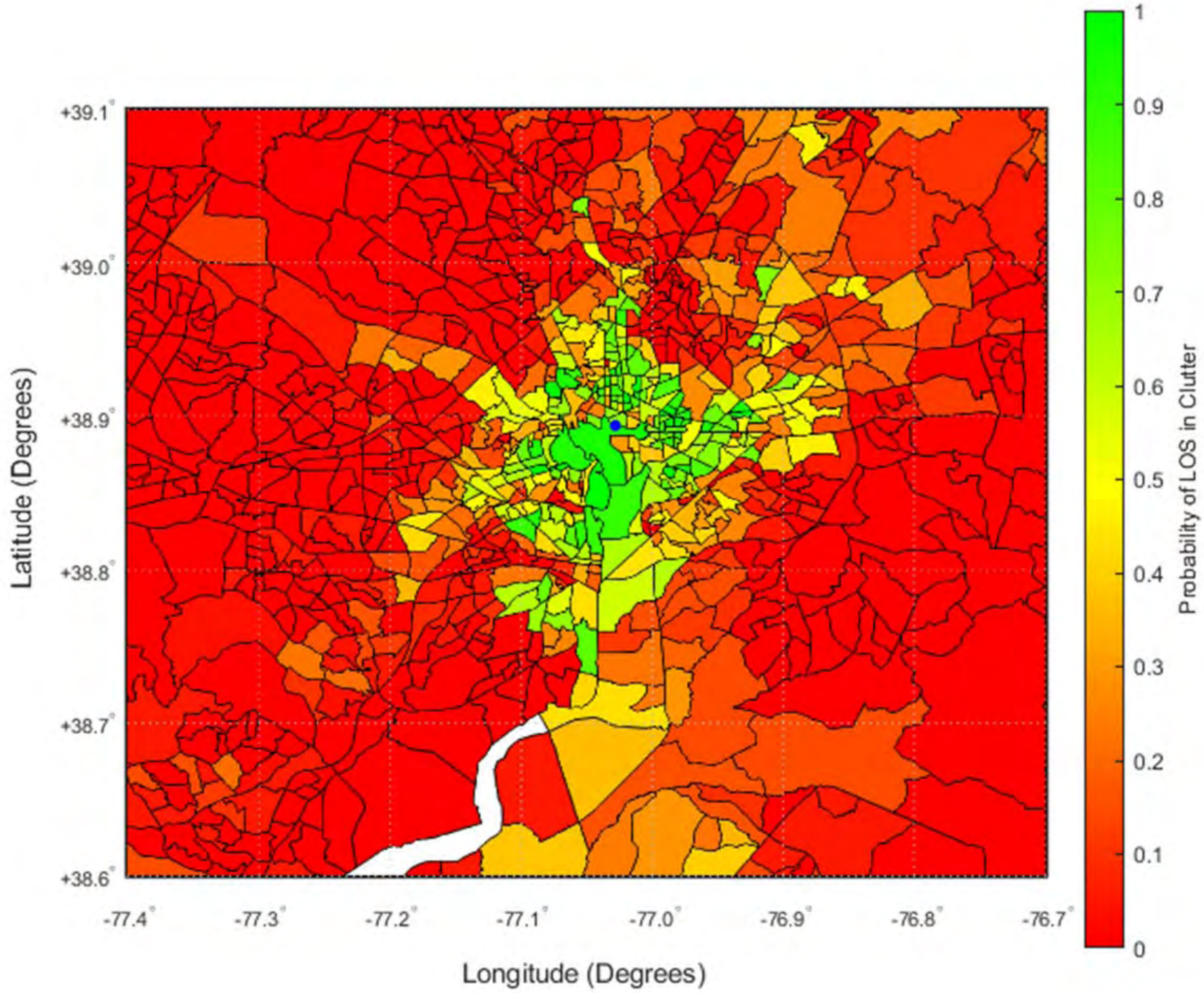

Figure 26. LOS Probability per census tract (Outdoor RLANs) to ENG central receive site at the Old Post Office

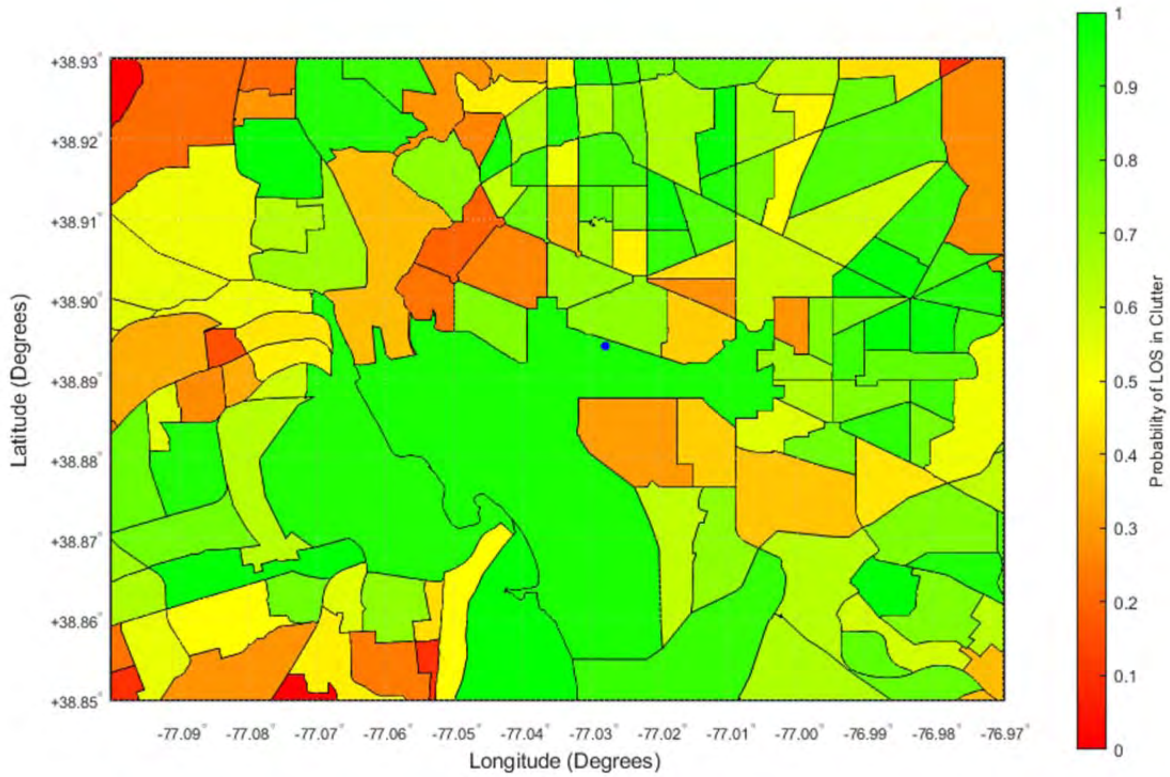

Figure 27. LOS Probability per census tract (Outdoor RLANs) to ENG central receive site at the Old Post Office (expanded view)

3.7 ENG TV TRUCK RECEIVERS

Two ENG truck locations in the Washington, DC area, one on C Street NW near the Washington, DC Mall and one in the parking lot in front of the PG County Courthouse, were also investigated. Since both the ENG truck and RLAN antennas were at relatively low heights, the probability of LOS links was expected to be low. The following figures show the LOS links for the RLAN grid points as a function of bearing angle and distance from the ENG trucks for each case investigated.

Figure 28 shows the LOS RLANs as a function of ENG receiver bearing and distance for the C Street NW ENG truck with a 1.5 m antenna height. Figure 29 shows the LOS RLANs for this ENG truck with a 15 m antenna height. For a visual reference, Figure 11 shows a Google Earth map for this ENG truck location. The C Street location is in an office ‘canyon’ and hundreds of office windows overlook the ENG TV truck location. It is highly likely that during a major news event the number of ‘active’ RLAN Wi-Fi transmitters could be much higher than that predicted here. The assumptions for this analysis are conservative and likely underestimate the actual number of RLAN Wi-Fi APs likely to be found in many use scenarios.

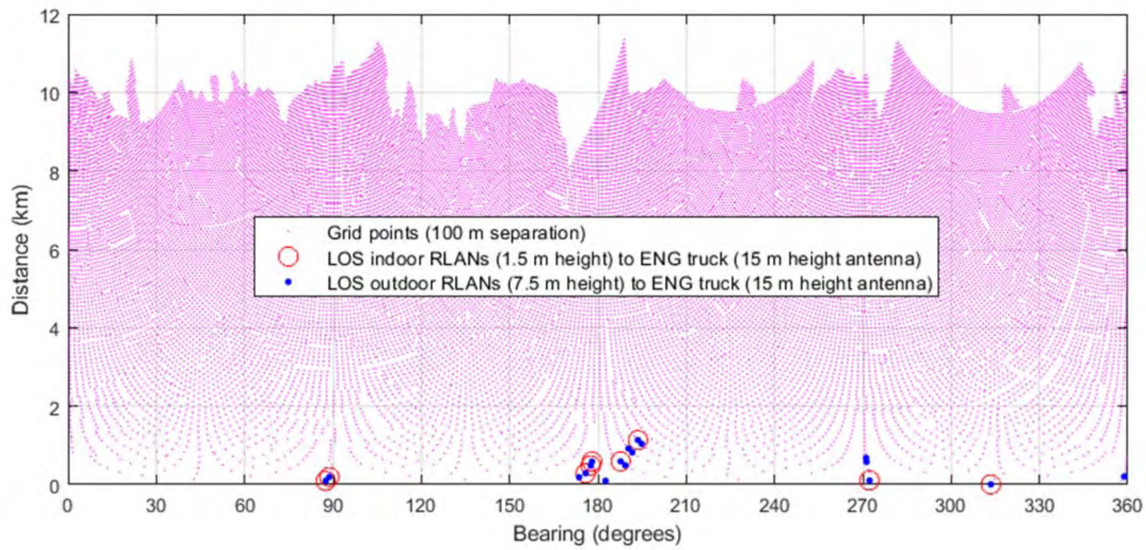

Figure 28. LOS RLANs vs. ENG receiver bearing and distance (from LiDAR data), RLANs to DC Mall ENG truck (1.5 m height antenna)

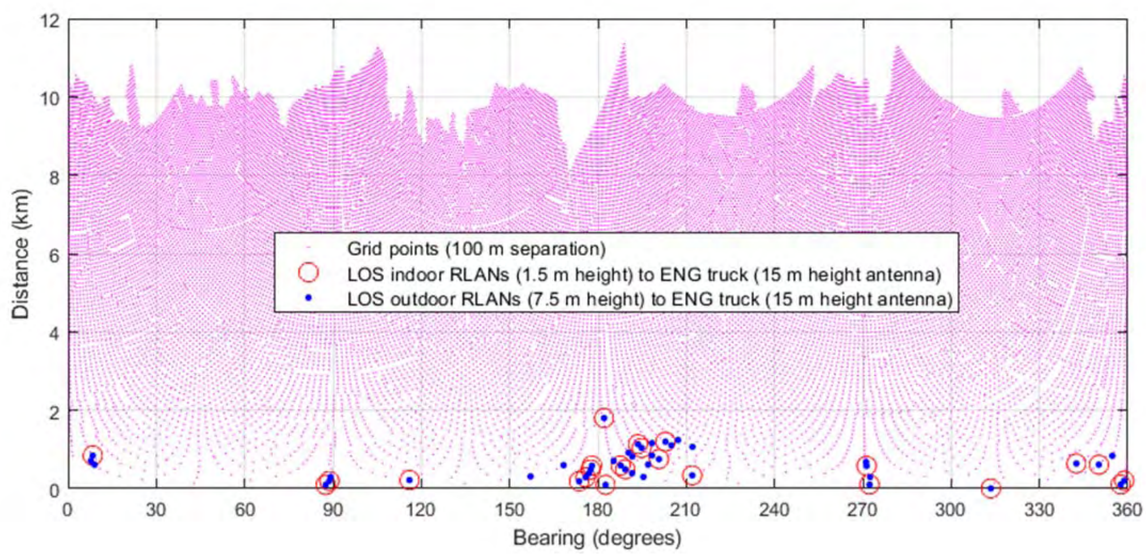

Figure 29. LOS RLANs vs. ENG receiver bearing and distance (from LiDAR data), RLANs to DC Mall ENG truck (15 m height antenna)

Figure 30 shows the LOS RLANs as a function of ENG receiver bearing and distance for the PG County Courthouse ENG truck with a 1.5 m antenna height. Figure 31 shows the LOS RLANs for this ENG truck with a 15 m antenna height. For a visual reference, Figure 12 shows a Google Earth map for this ENG truck location.

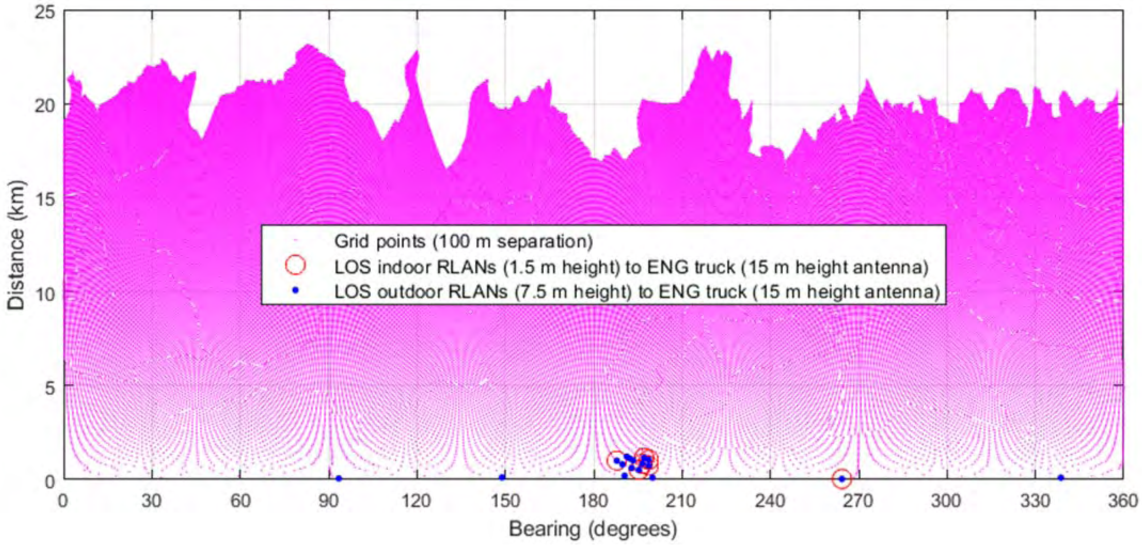

Figure 30. LOS RLANs vs. ENG receiver bearing and distance (from LiDAR data), RLANs to PG County Courthouse ENG truck (1.5 m height antenna)

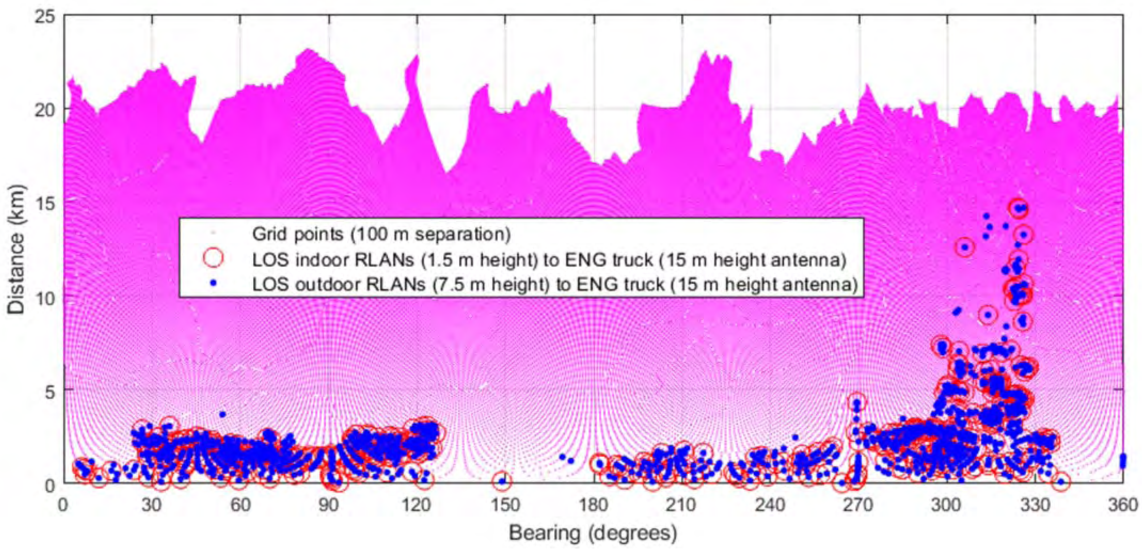

Figure 31. LOS RLANs vs. ENG receiver bearing and distance (from LiDAR data), RLANs to PG County Courthouse ENG truck (15 m height antenna)

3.8 ENG INTERIOR SCENARIO ANALYSIS ASSUMPTIONS

The objective of this analysis was to identify and assess the likelihood of RLAN EMI to the interior ENG receiver. Aggregate RLAN EMI to the ENG receiver was calculated for several RLAN densities and activities using a Monte Carlo model. For the interior analysis, due to the proximity of the RLANS to the ENG receiver, an adjacent-channel interference calculation capability was added to the Monte

Carlo model. The RLAN transmit emission mask[13] and an idealized ENG receiver selectivity was used to determine FDR curves as a function of RLAN bandwidth. These FDR curves were used to determine the rejection for off-tuned channel interference interactions.

Many of the assumptions for the ENG central receive site and ENG truck analyses also apply to the interior analysis. Following are characteristics and assumptions that are specific to the interior scenario analysis:

- RLANs were assumed to be mounted on the Chamber ceiling at fixed locations.
- All interior RLANs were assumed to be LOS to the ENG receive antenna.
- The ENG receive antenna was mounted on the railing of the House Gallery at a height of 16 feet (4.9 m) above the Chamber floor.
- The number of RLANs in the Chamber was varied parametrically for 4, 20, and 50 RLANs.
- The ENG receive antenna was assumed to be a 3 dBi omnidirectional antenna (Vislink L3535) which is an antenna typically used in interior ENG applications.
- RLANs were modeled as in the previous ENG Monte Carlo analyses as indoor RLANs with two exceptions:
    - The first exception involved the interior ceiling-mounted RLAN antenna model. In the previous analyses indoor RLAN antennas were modeled based on ITU recommendations as omnidirectional in azimuth but with a specific elevation pattern. It was assumed that the ITU elevation pattern was for a typical Wi-Fi router tabletop horizontal orientation. Since the RLANs in the U.S. House Chamber interior scenario were mounted on the ceiling, the elevation pattern orientation was unknown. Therefore, it was assumed that the ceiling-mounted RLAN antenna patterns were 0 dBi gain and isotropic in azimuth and elevation.
    - The second exception involved the proportion of 6 GHz-capable RLANs. For the interior analysis, all RLANs were assumed to be 6 GHz-capable. For the previous scenarios, 50% of the RLANs were assumed to be 6 GHz-capable since for the general population, legacy dual-band-only (2 GHz/5 GHz) Wi-Fi routers would likely exist for several years. However, for the House Chamber it seems likely that RLANs would be upgraded more regularly than for the general population.
- RLAN on-tune and adjacent-channel EMI were determined.
- Activity factors of 10% and 0.44% were investigated.
- The Monte Carlo model was run for 1 million snapshots (iterations).

[13] ITU-R M.1450-5, “Characteristics of broadband radio local area networks,” Geneva, February 2014.

3.9 ENG INTERIOR SCENARIO ADJACENT-CHANNEL EMI

In addition to on-tune EMI from RLANs, adjacent-channel interference was also calculated at the ENG interior scenario receiver. The RLAN OOBE characteristics are shown in Figure 32 (ITU-R M.1450-5). The measured ENG receiver IF selectivity was not available. Therefore, the receiver selectivity was conservatively modeled as an idealized 20 MHz IF bandwidth filter with 60 dB of rejection outside of the 20 MHz pass band. The RLAN transmit emission spectrum mask is dependent upon the RLAN channel bandwidth. Therefore, FDR curves were determined using the Microcomputer Spectrum Analysis Models (MSAM). MSAM is a suite of RF analysis tools developed by NTIA. The RLAN transmit spectrum and ENG receiver selectivity for RLAN bandwidths of 20, 40, 80, and 160 MHz are shown in Figure 33, Figure 34, Figure 35, and Figure 36, respectively. The FDR curves for RLAN bandwidths of 20, 40, 80, and 160 MHz are shown in Figure 37, Figure 38, Figure 39, and Figure 40, respectively.

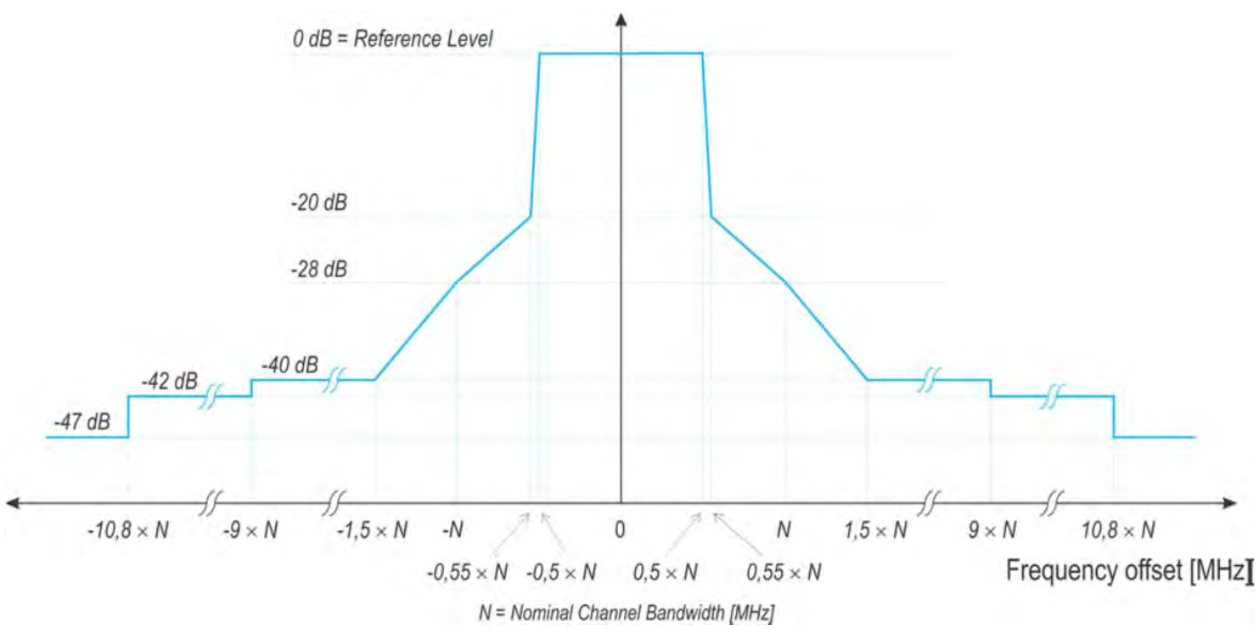

Figure 32. RLAN transmit emission spectrum mask

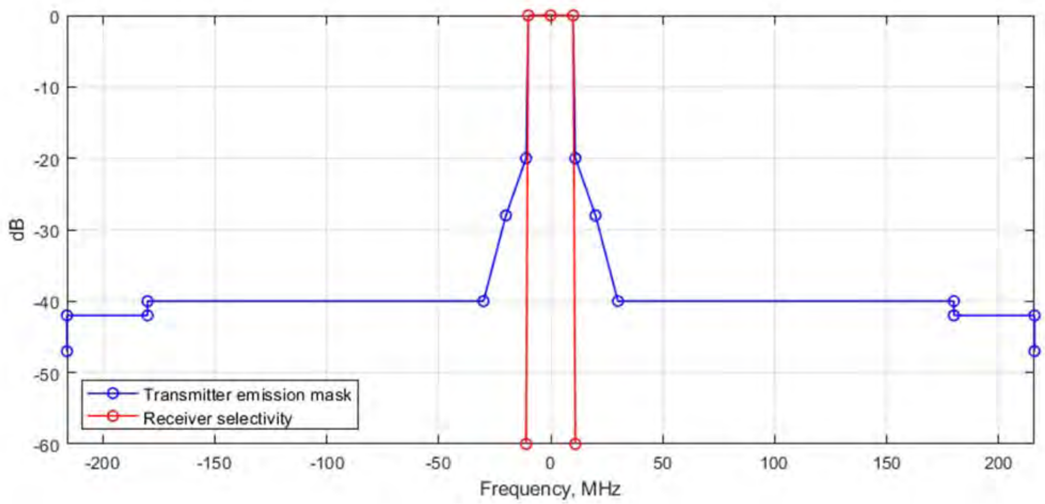

Figure 33. RLAN transmit 20 MHz bandwidth emission and ENG receiver selectivity

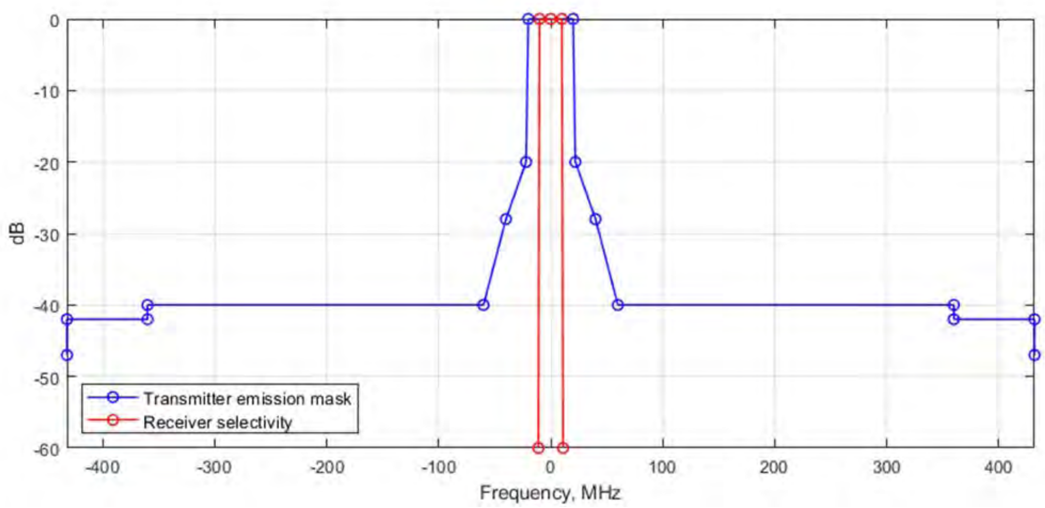

Figure 34. RLAN transmit 40 MHz bandwidth emission and ENG receiver selectivity

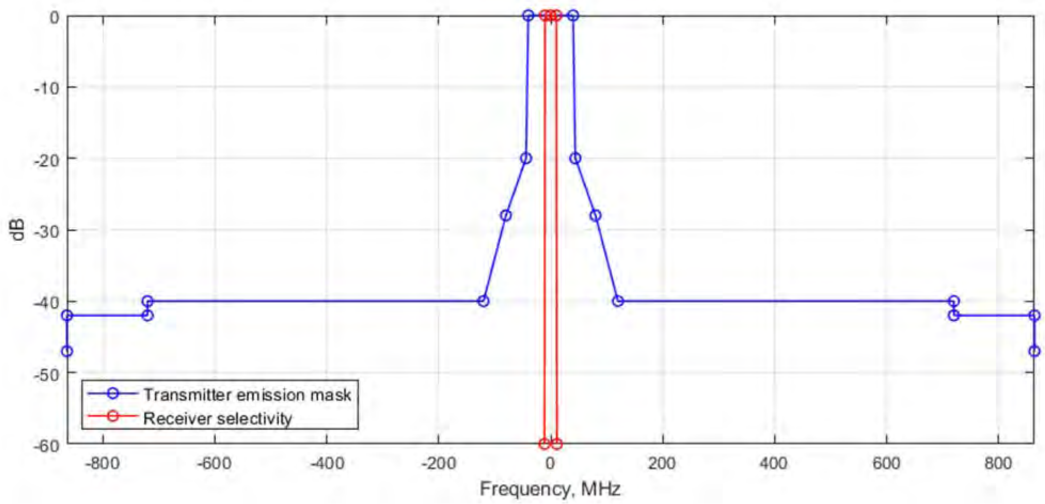

Figure 35. RLAN transmit 80 MHz bandwidth emission and ENG receiver selectivity

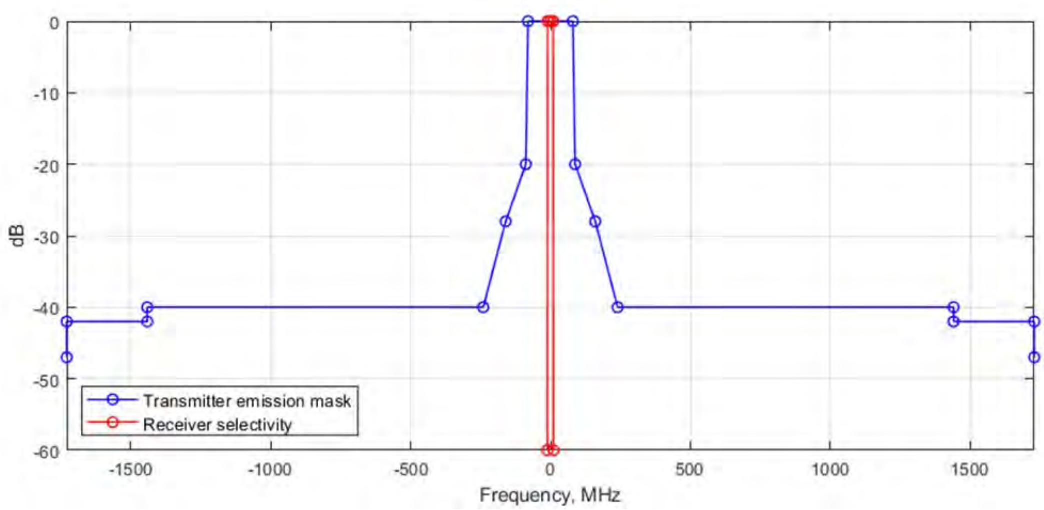

Figure 36. RLAN transmit 160 MHz bandwidth emission and ENG receiver selectivity

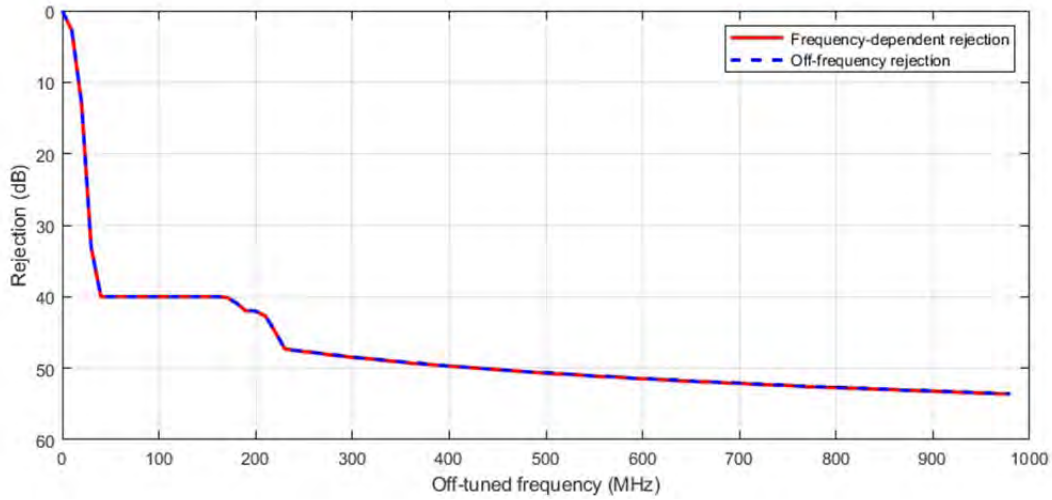

Figure 37. FDR for 20 MHz bandwidth RLAN

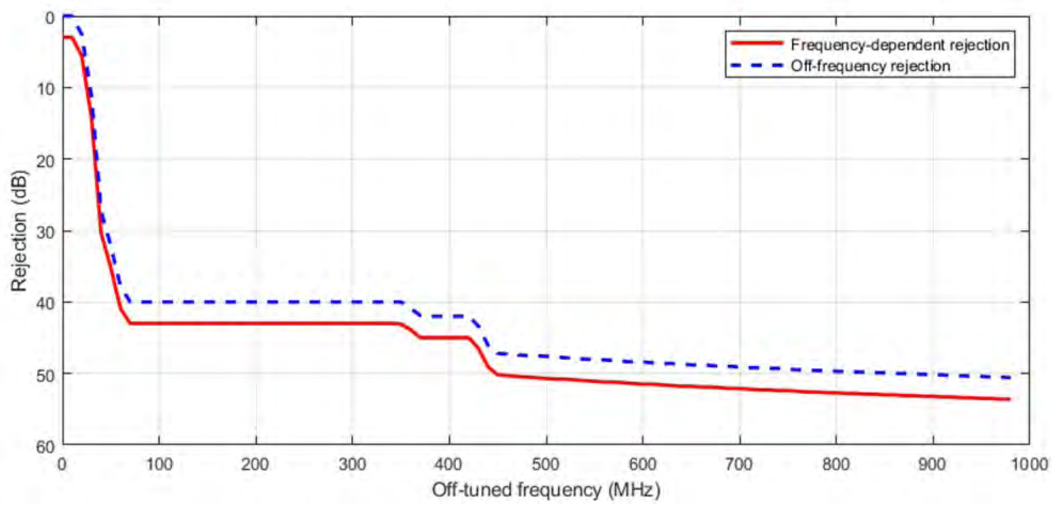

Figure 38. FDR for 40 MHz bandwidth RLAN

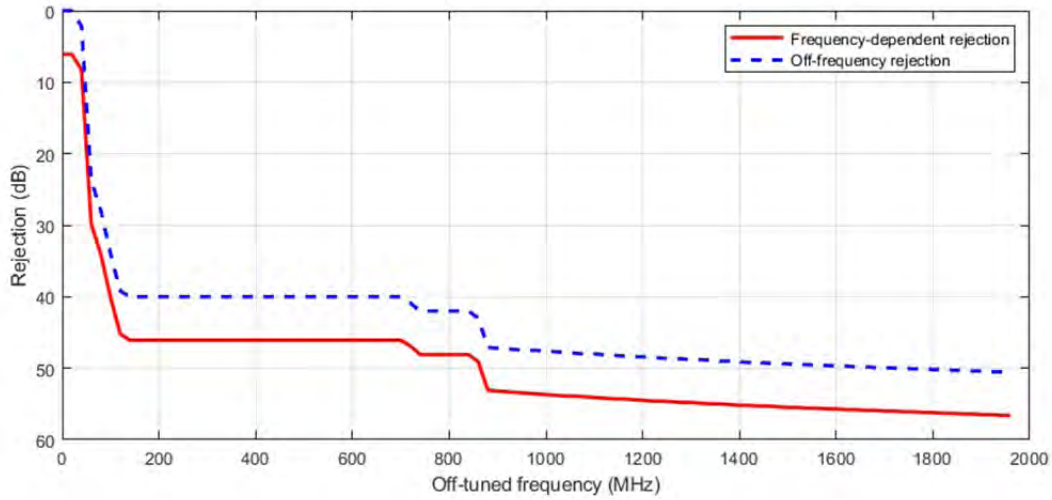

Figure 39. FDR for 80 MHz bandwidth RLAN

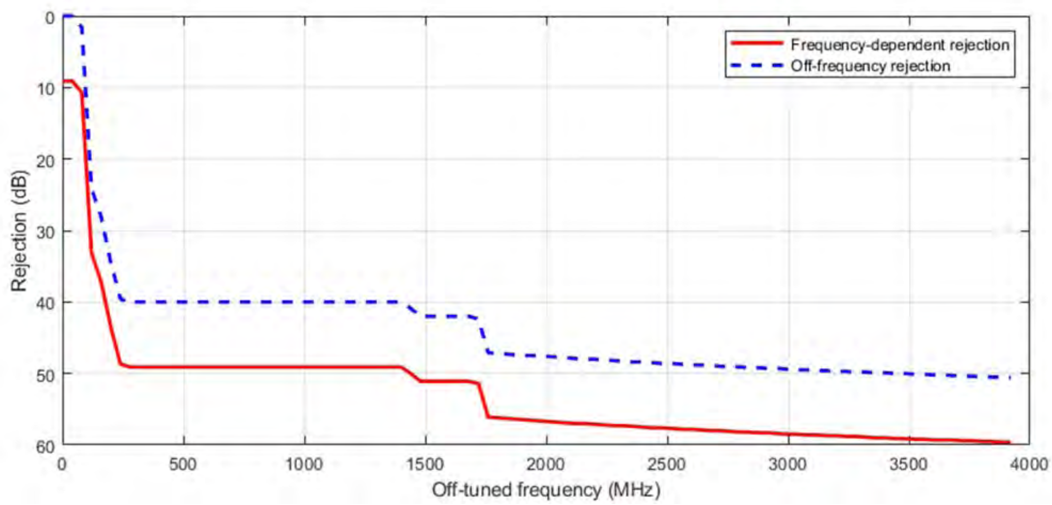

Figure 40. FDR for 160 MHz bandwidth RLAN

4.0 RESULTS

4.1 ENG CENTRAL RECEIVE SITE AND ENG TRUCK RESULTS

Table 12 shows a summary of ENG central receive site and ENG truck analysis results. Indoor and outdoor RLAN results are shown separately as well as the combined aggregate. Maximum single-entry (per snapshot) and aggregate interference results are also shown separately. The shaded column shows the percent of snapshots in which the aggregate I/N threshold was exceeded. For the two ENG central receive sites there were many cases of continuous or near-continuous EMI. This occurred most frequently for the 10% RLAN activity factor, but also occurred for the low 0.44% activity factor. The last two columns of the table show the maximum number of indoor and outdoor RLANs (per snapshot) that contributed to the interference levels. The ENG central receive sites, given their high antenna heights, were LOS to many RLANs resulting in high interference levels as well as a high probability of interference.

For each of the ENG sites, results were produced for several antenna azimuth angles. These cases show the effect of the ENG directional antenna pointing toward varying RLAN densities as defined by local census tracts.

For the ENG trucks, there were very few RLAN LOS links due to the much lower antenna heights. However, significant intermittent EMI was predicted for the ENG trucks with an activity factor of 10% and an antenna height of 15 m. Much less interference was predicted for the low activity factor and lower antenna height, but in many cases the interference threshold was still exceeded.

Appendix A provides detailed results distributions and associated statistics for each of the cases shown in the summary table.

Table 12. Central receive site and ENG truck analysis results summary

ENG receiver location	Rx antenna	Activity (%)	Antenna azimuth angle (deg)	% Indoor RLAN max. single-entry above I/N threshold	% Outdoor RLAN max. single-entry above I/N threshold	% Indoor RLAN aggregate above I/N threshold	% Outdoor RLAN aggregate above I/N threshold	% All RLANs aggregate above I/N threshold	% of snapshots with no indoor RLAN contributor	% of snapshots with no outdoor RLAN contributor	% of snapshots with no RLAN contributor	Max. number of indoor RLAN contributors	Max. number of outdoor RLAN contributors
Cowles Mtn.	ProScan	10	227	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	2130	218
Cowles Mtn.	ProScan	0.44	227	83.1	51.6	91.9	54.5	97.4	0.0	0.0	0.0	122	21
Cowles Mtn.	ProScan	10	194	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	2104	214
Cowles Mtn.	ProScan	0.44	194	86.5	61.2	95.8	65.5	99.2	0.0	0.1	0.0	124	20
Cowles Mtn.	ProScan	10	108	100.0	99.3	100.0	100.0	100.0	0.0	0.0	0.0	2136	211
Cowles Mtn.	ProScan	0.44	108	46.0	20.5	50.7	22.5	65.0	0.0	0.1	0.0	121	21
DC Post Office	ProScan	10	94	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	724	121
DC Post Office	ProScan	0.44	94	53.2	37.2	59.3	41.0	80.0	0.0	1.9	0.0	49	13
DC Post Office	ProScan	10	315	98.9	99.5	100.0	100.0	100.0	0.0	0.0	0.0	728	130
DC Post Office	ProScan	0.44	315	18.4	20.6	21.0	24.7	45.9	0.0	1.9	0.0	49	13
DC Post Office	ProScan	10	180	97.9	99.4	100.0	100.0	100.0	0.0	0.0	0.0	742	129
DC Post Office	ProScan	0.44	180	15.7	19.5	18.8	23.4	44.1	0.0	2.1	0.0	52	12
DC ENG Truck	Omni 1.5 m	10	---	15.6	4.2	15.7	4.2	19.2	66.7	95.8	64.0	5	2
DC ENG Truck	Omni 15 m	10	---	38.0	11.9	39.2	11.9	46.6	28.1	88.1	24.7	8	3
DC ENG Truck	Omni 1.5 m	0.44	---	0.0	0.0	0.0	0.0	0.0	100.0	100.0	100.0	0	0
DC ENG Truck	Omni 15 m	0.44	---	2.2	0.5	2.2	0.5	2.7	94.4	99.5	93.9	2	1
PG ENG Truck	Omni 1.5 m	10	---	0.2	0.2	0.2	0.2	0.4	98.1	99.7	97.8	2	1
PG ENG Truck	Omni 15 m	10	---	22.5	29.1	25.6	29.4	48.7	4.5	60.1	2.9	11	5
PG ENG Truck	Omni 1.5 m	0.44	---	0.0	0.0	0.0	0.0	0.0	99.9	100.0	99.9	1	1
PG ENG Truck	Omni 15 m	0.44	---	1.0	1.4	1.0	1.4	2.5	88.1	97.8	86.2	3	2
DC ENG Truck	Sector 1.5 m	10	290	16.8	4.4	16.9	4.4	20.5	65.6	95.6	63.0	5	2
DC ENG Truck	Sector 15 m	10	290	41.5	12.3	42.5	12.3	49.6	27.5	87.8	24.3	8	3
DC ENG Truck	Sector 1.5 m	0.44	290	0.9	0.2	0.9	0.2	1.1	98.3	99.9	98.1	1	1
DC ENG Truck	Sector 15 m	0.44	290	2.2	0.5	2.2	0.5	2.7	94.6	99.5	94.1	2	1
DC ENG Truck	Sector 1.5 m	10	180	14.3	4.3	14.5	4.3	18.2	65.5	95.6	62.8	4	2
DC ENG Truck	Sector 15 m	10	180	34.7	11.5	35.9	11.5	43.4	26.5	88.3	23.3	7	3
DC ENG Truck	Sector 1.5 m	0.44	180	0.7	0.2	0.7	0.2	0.9	98.1	99.8	97.9	1	1
DC ENG Truck	Sector 15 m	0.44	180	1.9	0.5	1.9	0.5	2.5	94.2	99.5	93.7	2	2
PG ENG Truck	Sector 1.5 m	10	290	0.2	0.2	0.2	0.2	0.4	98.3	99.7	98.0	1	1
PG ENG Truck	Sector 15 m	10	290	46.5	33.4	49.8	33.6	66.9	4.4	59.5	2.4	12	5
PG ENG Truck	Sector 1.5 m	0.44	290	0.0	0.0	0.0	0.0	0.0	99.9	100.0	99.9	1	1
PG ENG Truck	Sector 15 m	0.44	290	2.8	1.9	2.8	1.9	4.6	87.4	97.8	85.5	3	3
PG ENG Truck	Sector 1.5 m	10	100	0.4	0.3	0.4	0.3	0.6	98.2	99.7	97.9	1	1
PG ENG Truck	Sector 15 m	10	100	21.6	26.2	24.3	26.5	45.2	4.4	59.8	2.6	11	6
PG ENG Truck	Sector 1.5 m	0.44	100	0.0	0.0	0.0	0.0	0.0	99.9	100.0	99.9	1	1
PG ENG Truck	Sector 15 m	0.44	100	0.9	1.4	0.9	1.4	2.3	87.4	97.7	85.4	3	2

4.2 ENG INTERIOR SCENARIO RESULTS

Table 13 shows a summary of the interior scenario analysis results including adjacent channel interference. Maximum single-entry (per snapshot) and aggregate interference results are also shown separately. The fourth (shaded) column shows the percent of snapshots in which the aggregate I/N threshold was exceeded. For this scenario there were many cases of continuous or near-continuous EMI at the 10% RLAN activity factor. Occurrences of EMI were also found for the low 0.44% activity factor. The last column of the table shows the maximum number of RLANs (per snapshot) that contributed to these high interference levels. The ENG receive antenna was LOS to all RLANs resulting in high interference levels as well as a high incidence of interference.

Appendix B provides detailed results distributions and associated statistics for each of the cases shown in the summary table.

As shown above, some ENG channels are expected to see adjacent channel out-of-band emissions and noise at 40 dB below the RLAN carrier level, resulting in elevation of the effective noise level in the IF bandwidth of the ENG receiver. If those channels are modeled at that level, the I/N threshold will likely be exceeded.

Table 13. Interior analysis summary results

Number of RLANs	Activity (%)	% RLAN max. single-entry above I/N threshold	% RLAN aggregate above I/N threshold	% of snapshots with no RLAN contributor	Max. number of RLAN contributors
4	10	18.8	19.1	65.6	4
4	0.44	0.9	0.9	98.2	2
20	10	63.4	67.2	12.1	10
20	0.44	4.2	4.2	91.6	4
50	10	91.7	95.3	0.5	18
50	0.44	10.2	10.3	80.2	5

5.0 CONCLUSIONS

The Alion analyses predict harmful RLAN EMI for typical ENG system deployment use cases. This EMI could potentially result in degradation or complete loss of ENG video signals. Figures 20 through 31 show how increased antenna heights increase the likelihood of LOS RLAN interactions with ENG systems and by extension increase the probability of interference. Likewise, Table 12 shows the significant effect RLAN activity factor has upon the probability of interference.

For the central receive deployment use cases in San Diego and Washington, DC, it is possible to see how antenna heights (in Figures 20-31) and activity factors (in Table 12) contributed to an increase in harmful interference interactions. When higher antennas were combined with a larger activity factor there were many cases of continuous or near-continuous interference at the ENG central receive sites. Continuous or near-continuous interference occurred most frequently for an RLAN activity factor of 10%, but also occurred even for the low activity factor of 0.44%. The ENG central receive sites, given their high antenna heights, were LOS to many RLANs resulting in the high EMI levels as well as a high incidence of interference.

For the Washington, DC and Prince George's County ENG truck deployment use cases investigated, the number of RLAN LOS links decreased as a function of the relationship between the height of the RLAN antennas, the height of the ENG truck antennas, and the heights of the surrounding buildings. In Washington DC neither the RLAN antennas nor the ENG truck antennas on masts were taller than the five and six story buildings found along C Street. Consequently, Figures 28 and 29 show very few RLAN LOS interactions. At the Prince George's County Courthouse (PGCC) there are fewer buildings and the buildings are not as tall as at the Washington, DC C Street ENG truck location, consequently there is an increase in the RLAN LOS interactions at the PGCC as shown in Figures 30 and 31.

In general, at both the C Street and PG County Courthouse ENG truck locations, less EMI was predicted when using the lower ENG truck antenna (1.5-meter height). However, significant intermittent EMI was predicted for an ENG truck using the antenna on the extended mast (15-meter height) and an RLAN activity factor of 10%. Much less interference was predicted for the 1.5-meter ENG truck antenna height and a low RLAN activity factor of 0.44%, but even in that case the interference threshold was still exceeded. This intermittent EMI will reduce the reliability of the ENG truck video links.

The interior analysis predicted EMI to the ENG receiver in the chamber of the US House of Representatives due to emissions from RLAN Wi-Fi transmit routers. Due to the high noise levels generated in the ENG IF filter by adjacent-band and out-of-band RLAN signals, ENG receiver desensitization and receiver degradation is also expected on a continuous basis.

APPENDIX A – DETAILED ENG CENTRAL RECEIVE SITE AND ENG TRUCK RESULTS (Cumulative Distributions and Summary Statistics)

This appendix provides detailed ENG central receive site and ENG truck results distributions for each of the cases shown in the summary table (Table 12). For each summary table entry, the following results distributions are provided:

- Maximum (per snapshot) single-entry RLAN I/N distribution for indoor and outdoor RLANs
- Aggregate RLAN I/N distribution for indoor, outdoor, and combined RLANs
- Number of indoor RLAN contributors per snapshot
- Number of outdoor RLAN contributors per snapshot

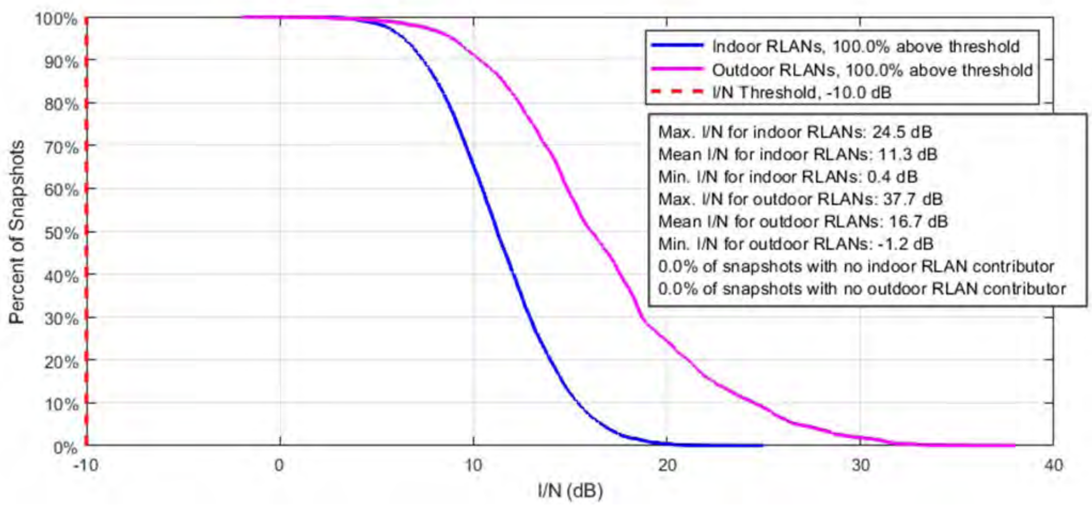

Figure 41. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 10%, antenna azimuth angle = 227 degrees (toward San Diego)

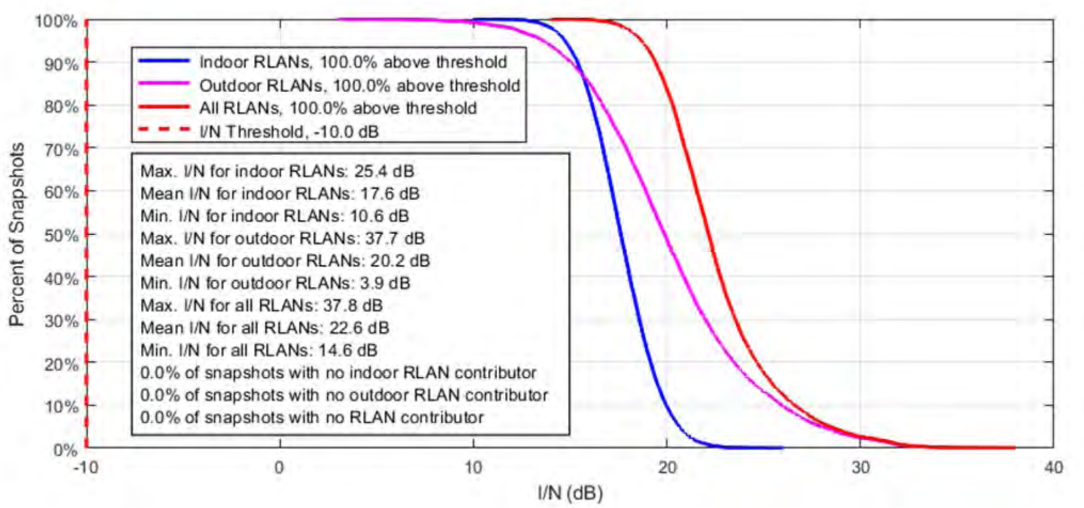

Figure 42. Aggregate RLAN I/N distribution, Cowles Mountain, activity = 10%, antenna azimuth angle = 227 degrees (toward San Diego)

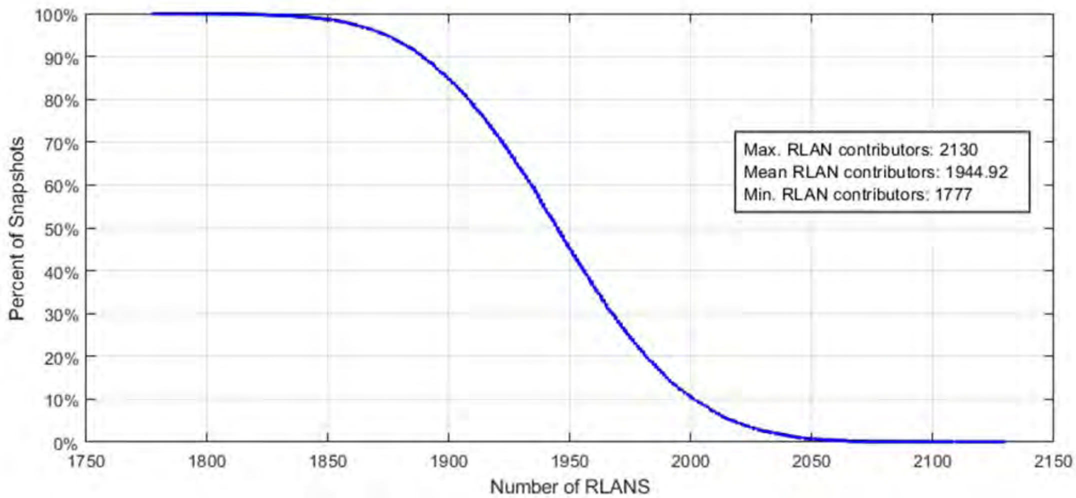

Figure 43. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 10%, antenna azimuth angle = 227 degrees (toward San Diego)

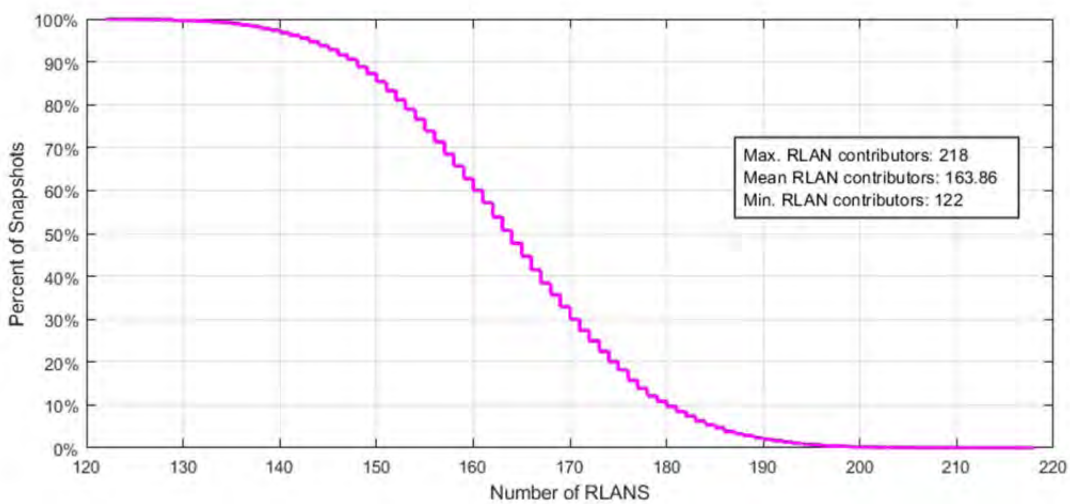

Figure 44. Number of outdoor RLAN contributors per snapshot Cowles Mountain, activity = 10%, antenna azimuth angle = 227 degrees (toward San Diego)

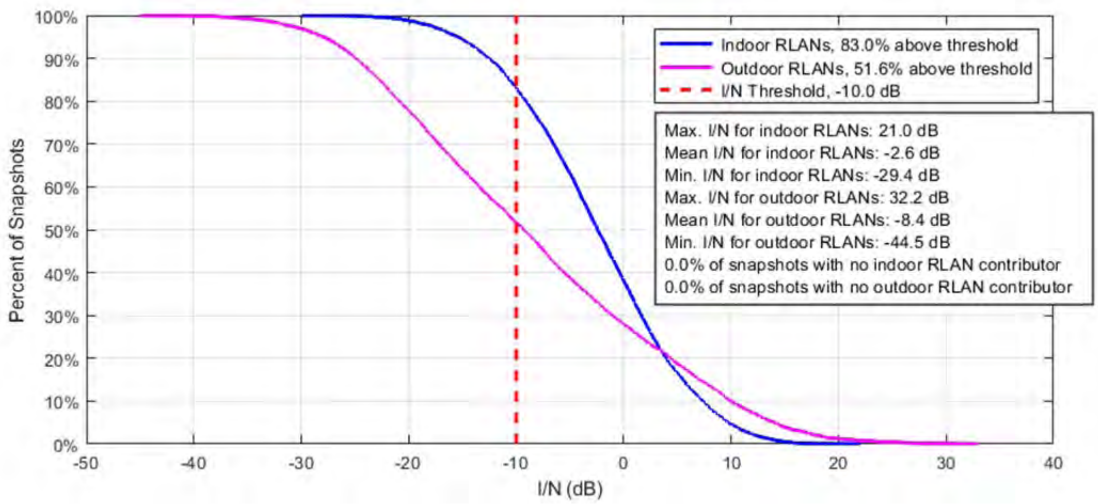

Figure 45. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 227 degrees (toward San Diego)

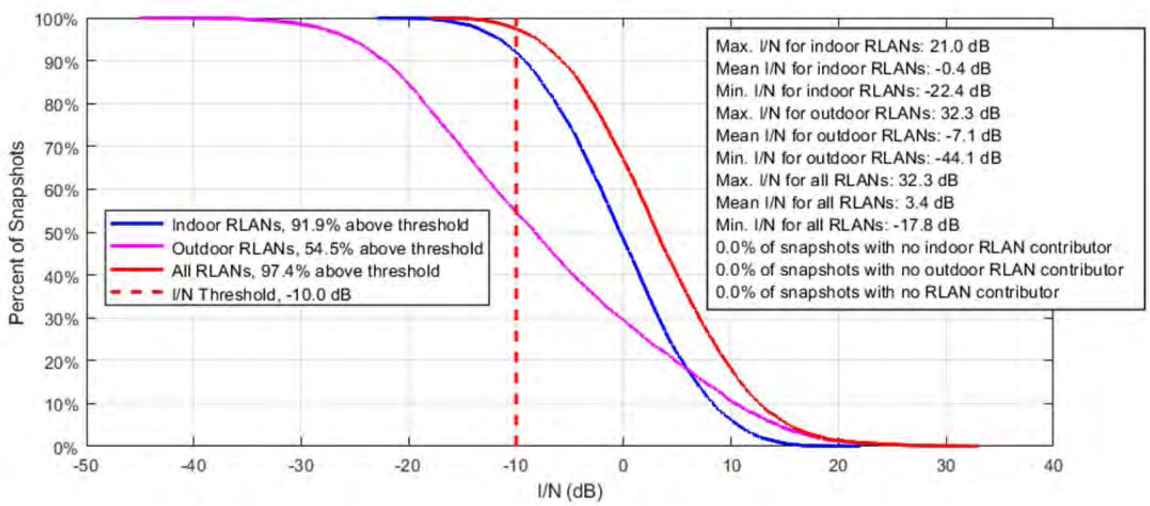

Figure 46. Aggregate RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 227 degrees (toward San Diego)

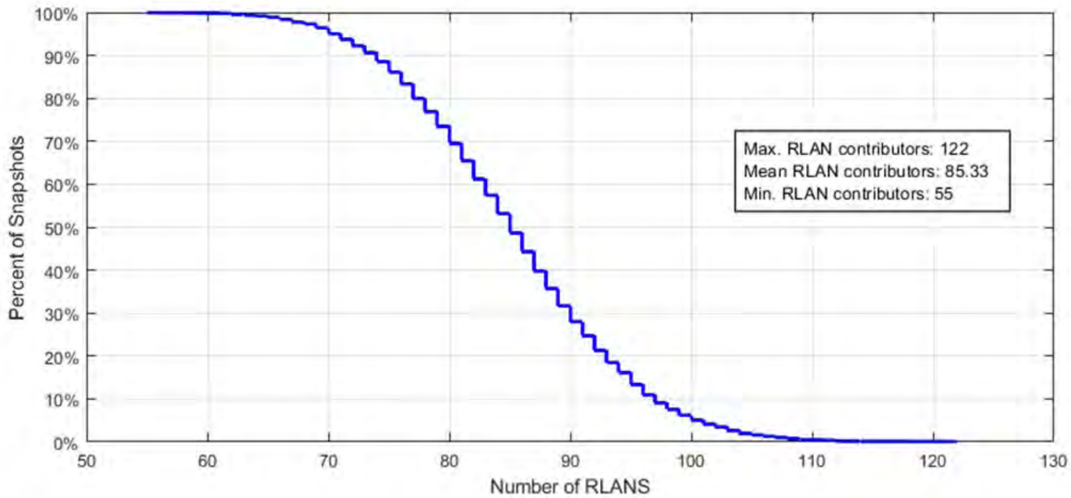

Figure 47. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 227 degrees (toward San Diego)

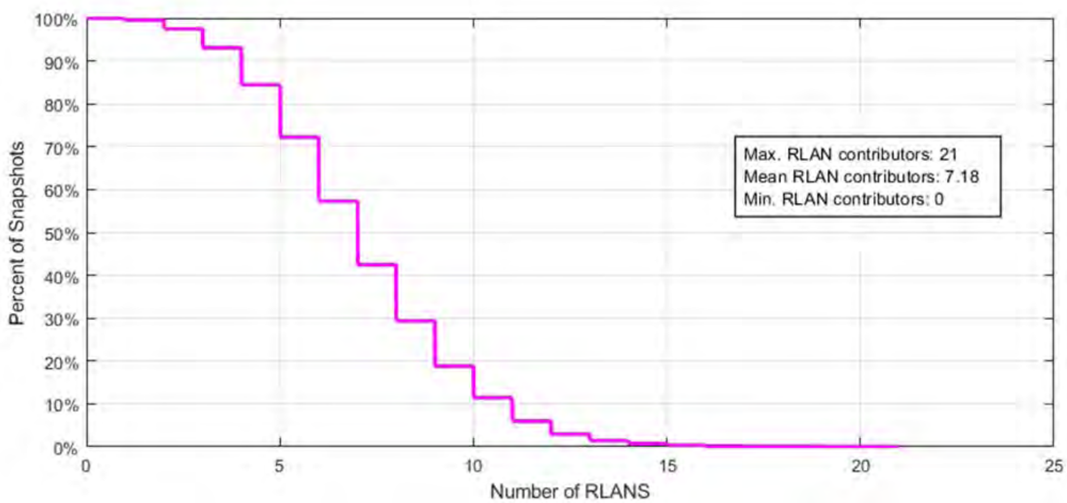

Figure 48. Number of outdoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 227 degrees (toward San Diego)

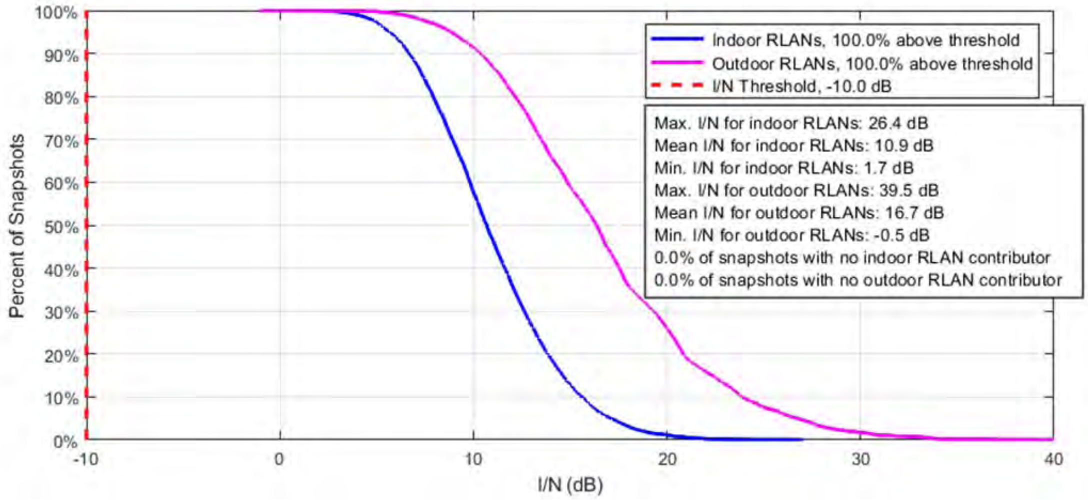

Figure 49. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 10%, antenna azimuth angle = 194 degrees (toward Chula Vista)

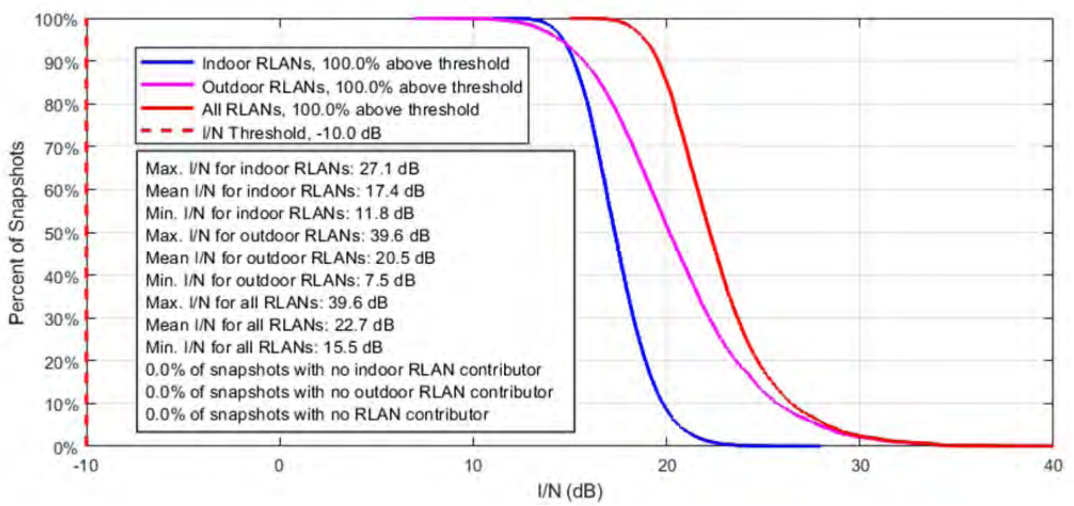

Figure 50. Aggregate RLAN I/N distribution, Cowles Mountain, activity = 10%, antenna azimuth angle = 194 degrees (toward Chula Vista)

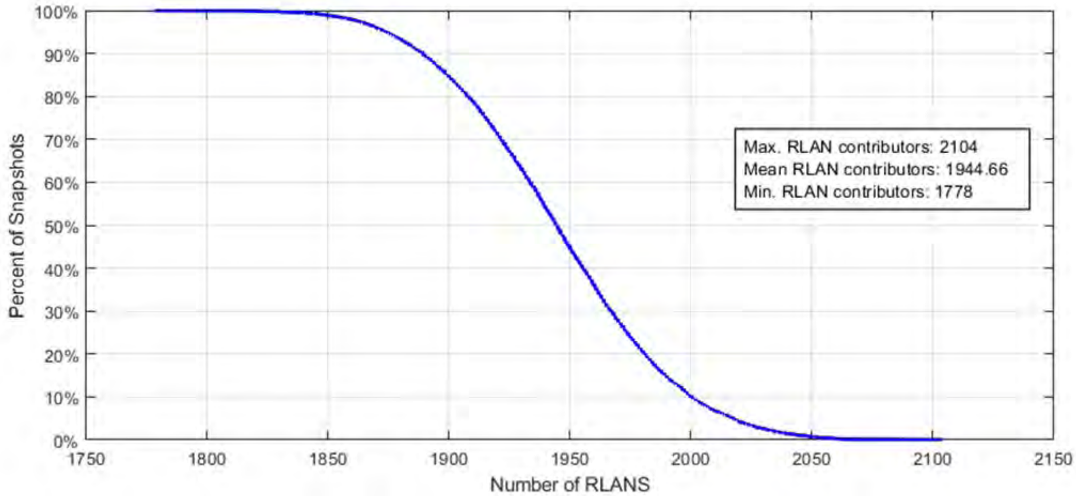

Figure 51. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 10%, antenna azimuth angle = 194 degrees (toward Chula Vista)

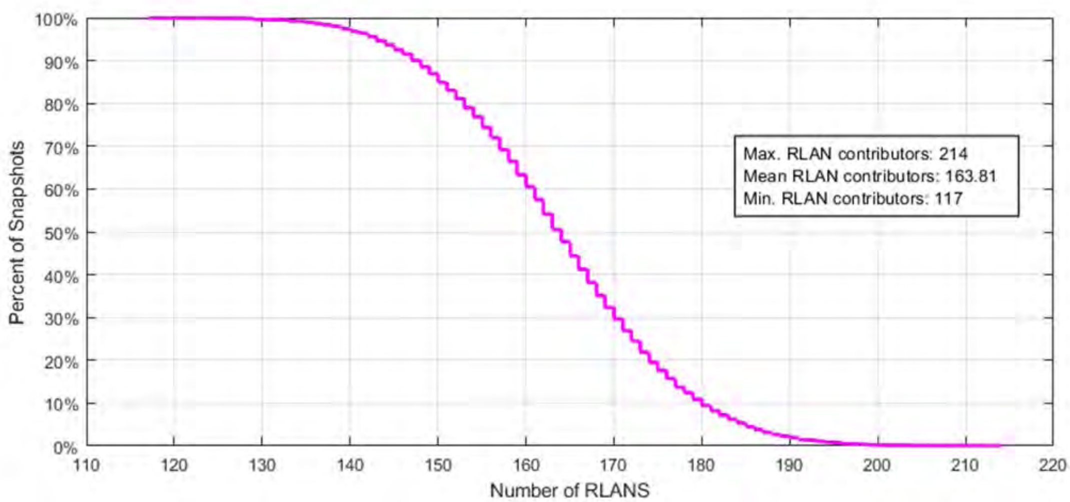

Figure 52. Number of outdoor RLAN contributors per snapshot, Cowles Mountain, activity = 10%, antenna azimuth angle = 194 degrees (toward Chula Vista)

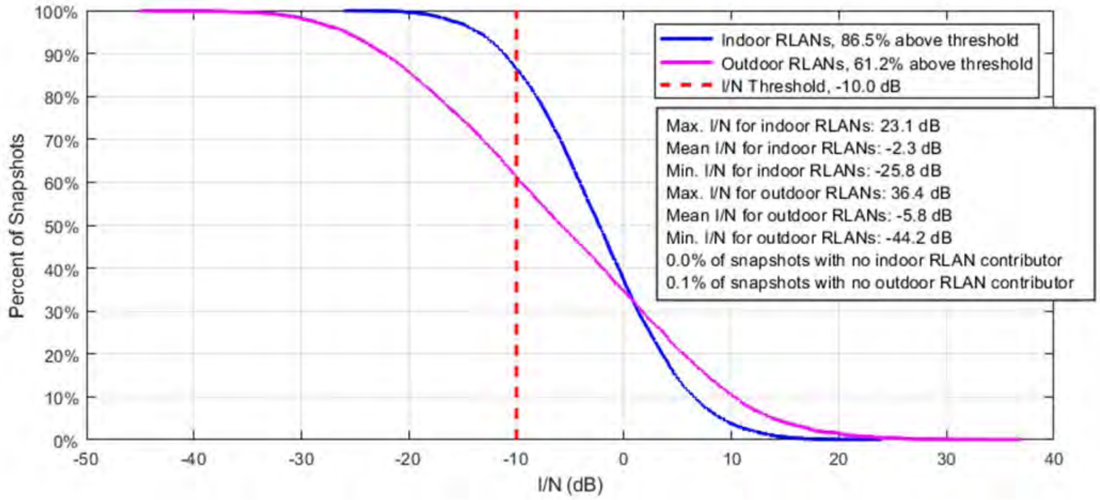

Figure 53. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 194 degrees (toward Chula Vista)

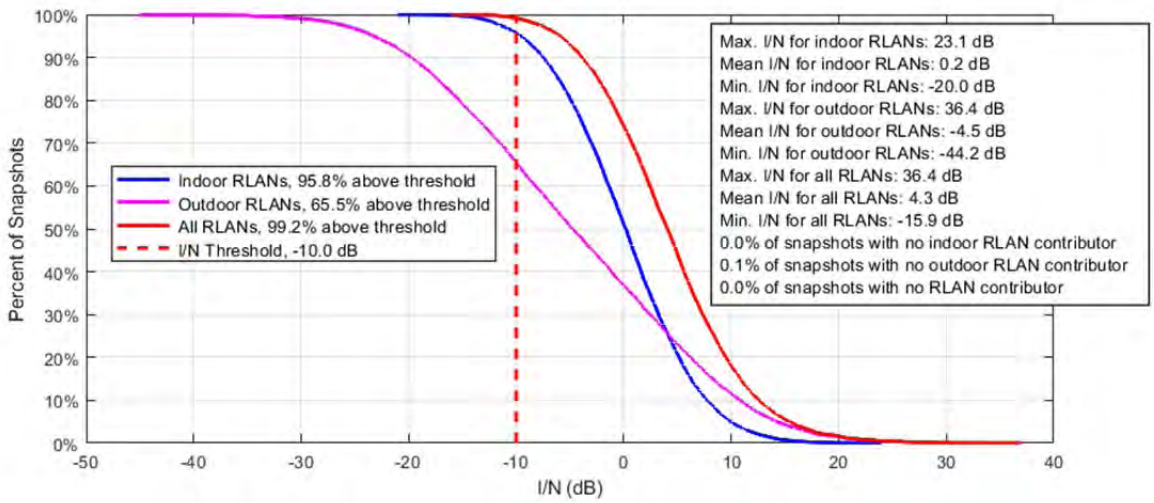

Figure 54. Aggregate RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 194 degrees (toward Chula Vista)

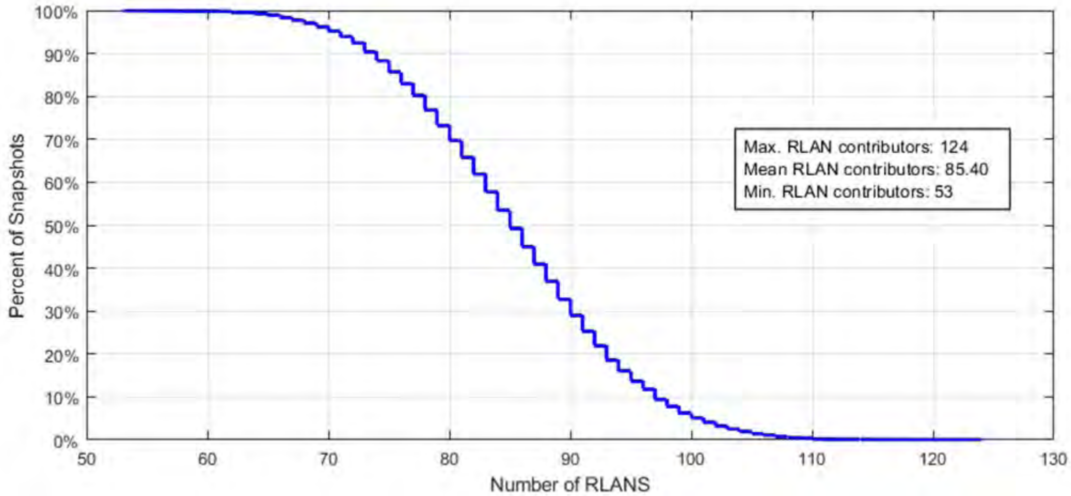

Figure 55. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 194 degrees (toward Chula Vista)

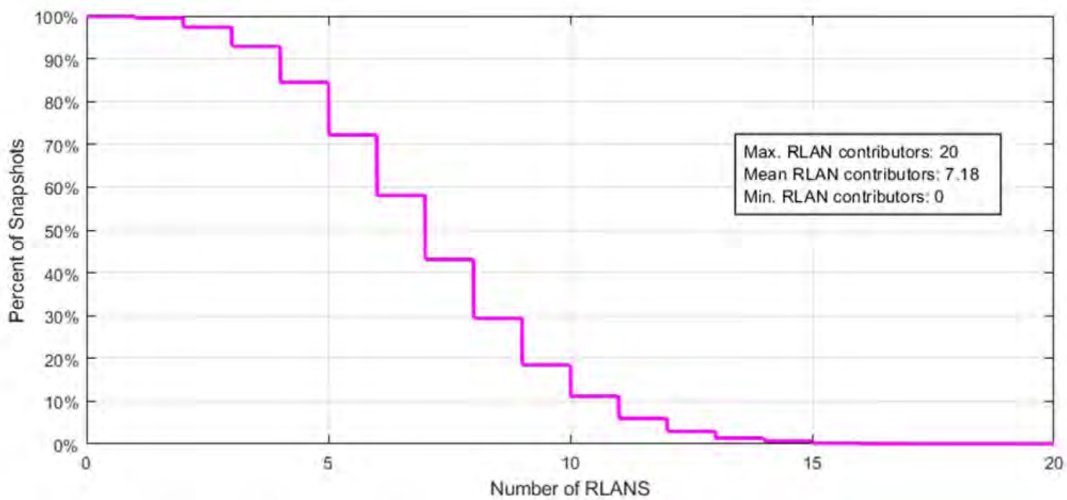

Figure 56. Number of outdoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 194 degrees (toward Chula Vista)

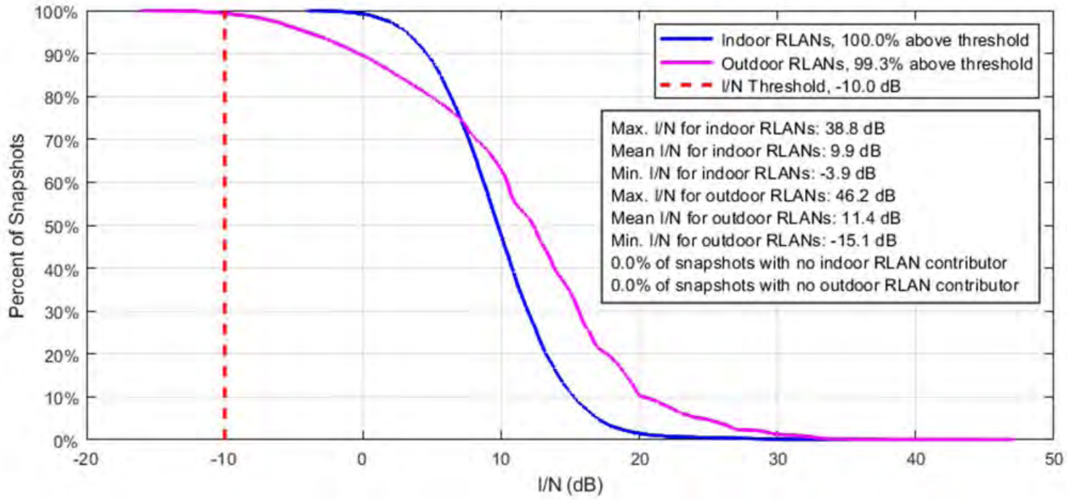

Figure 57. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 10%, antenna azimuth angle = 108 degrees (toward El Cajon)

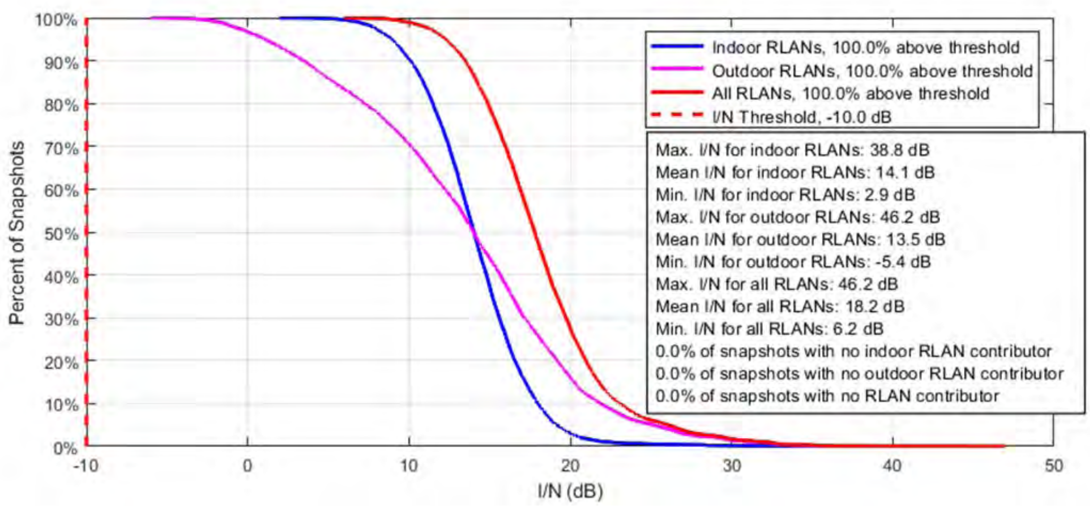

Figure 58. Aggregate RLAN I/N distribution, Cowles Mountain., activity = 10%, antenna azimuth angle = 108 degrees (toward El Cajon)

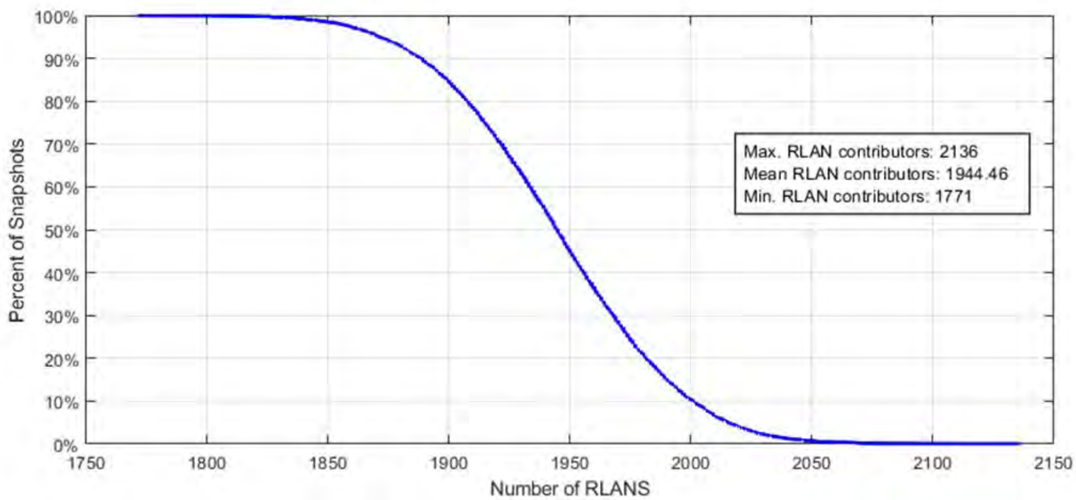

Figure 59. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 10%, antenna azimuth angle = 108 degrees (toward El Cajon)

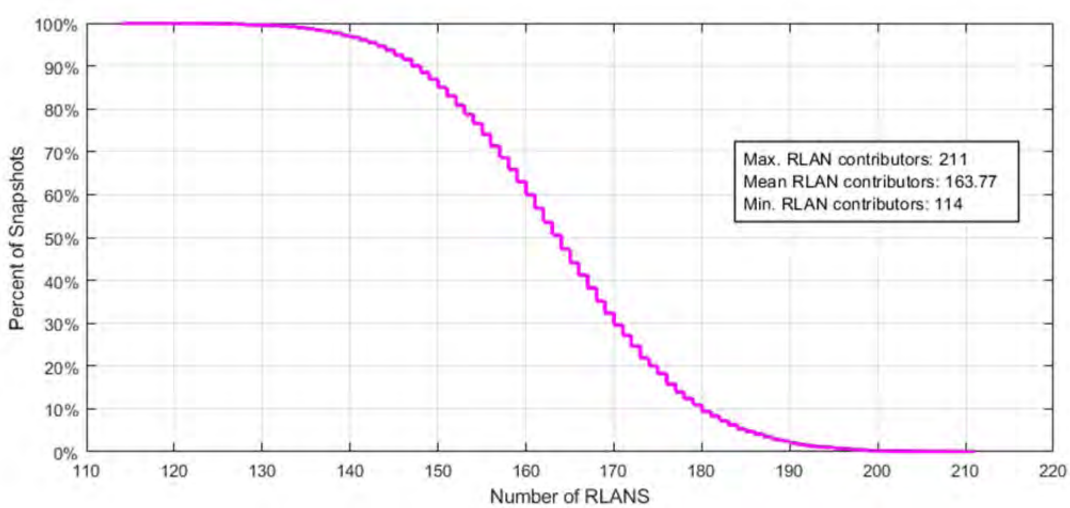

Figure 60. Number of outdoor RLAN contributors per snapshot, Cowles Mountain, activity = 10%, antenna azimuth angle = 108 degrees (toward El Cajon)

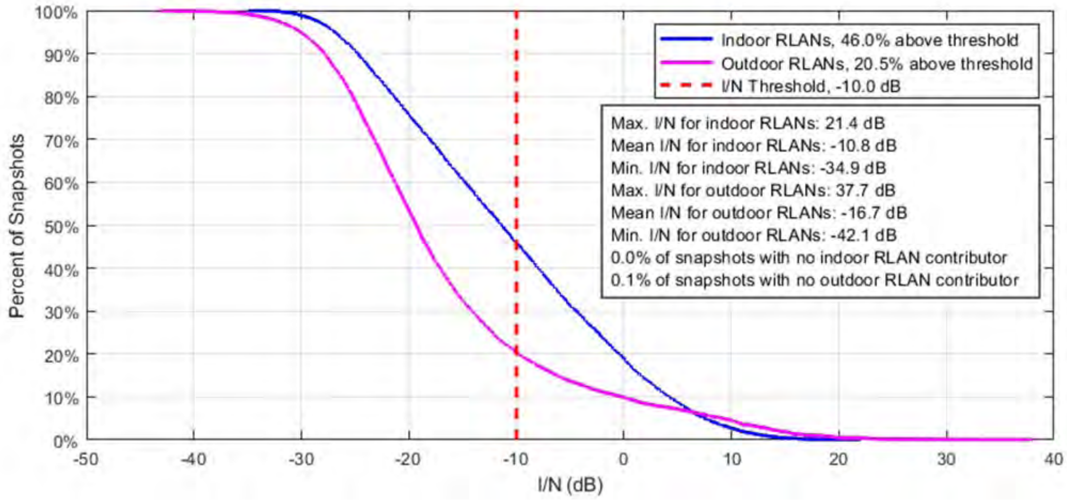

Figure 61. Max. single-entry RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 108 degrees (toward El Cajon)

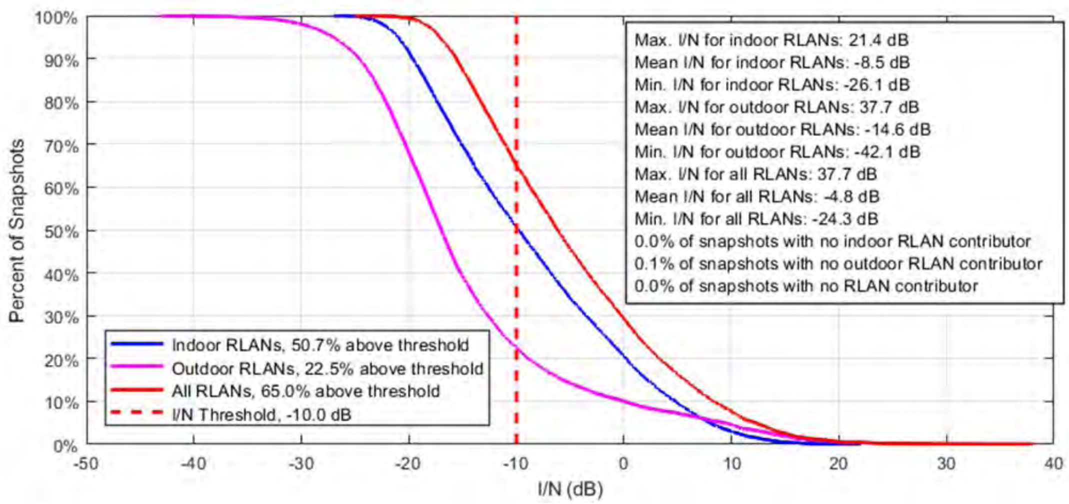

Figure 62. Aggregate RLAN I/N distribution, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 108 degrees (toward El Cajon)

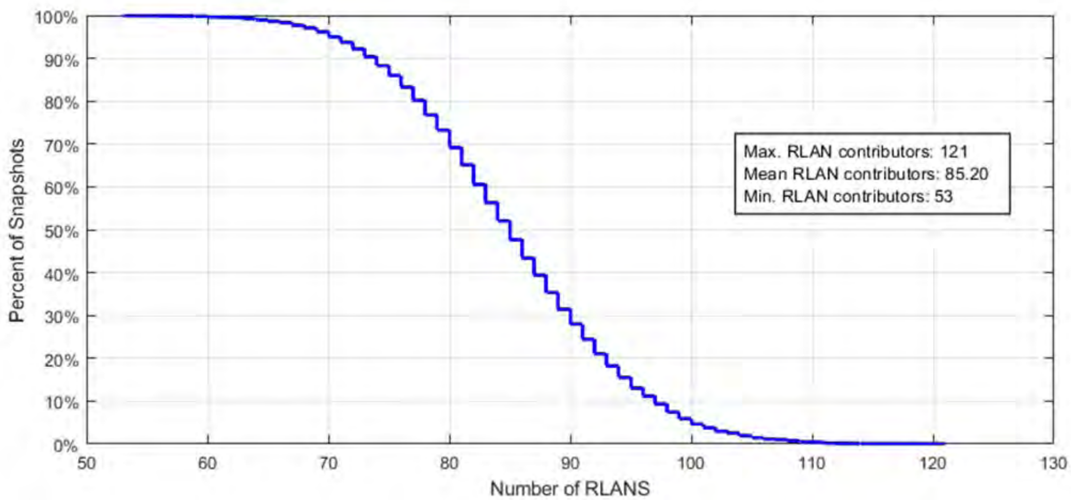

Figure 63. Number of indoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 108 degrees (toward El Cajon)

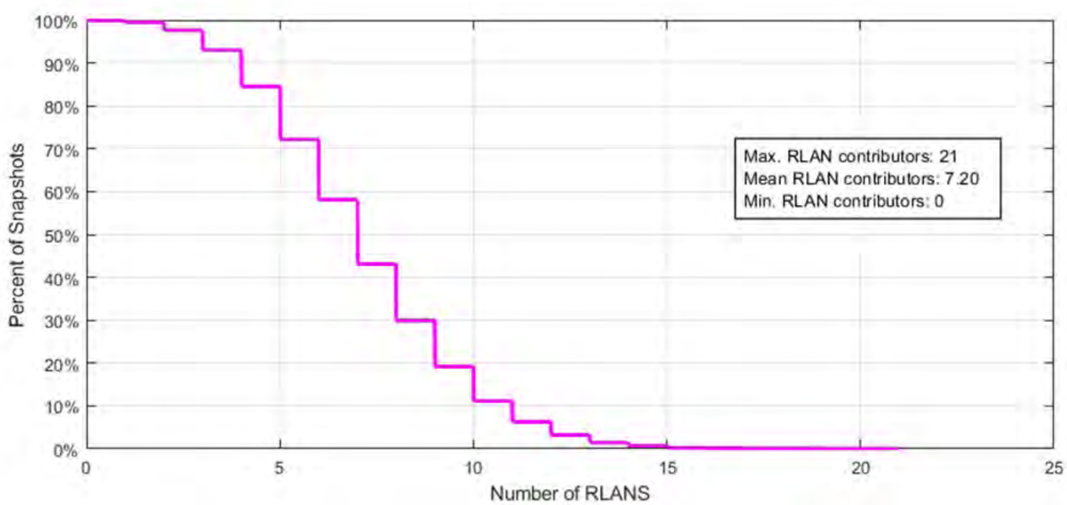

Figure 64. Number of outdoor RLAN contributors per snapshot, Cowles Mountain, activity = 0.44%, antenna azimuth angle = 108 degrees (toward El Cajon)

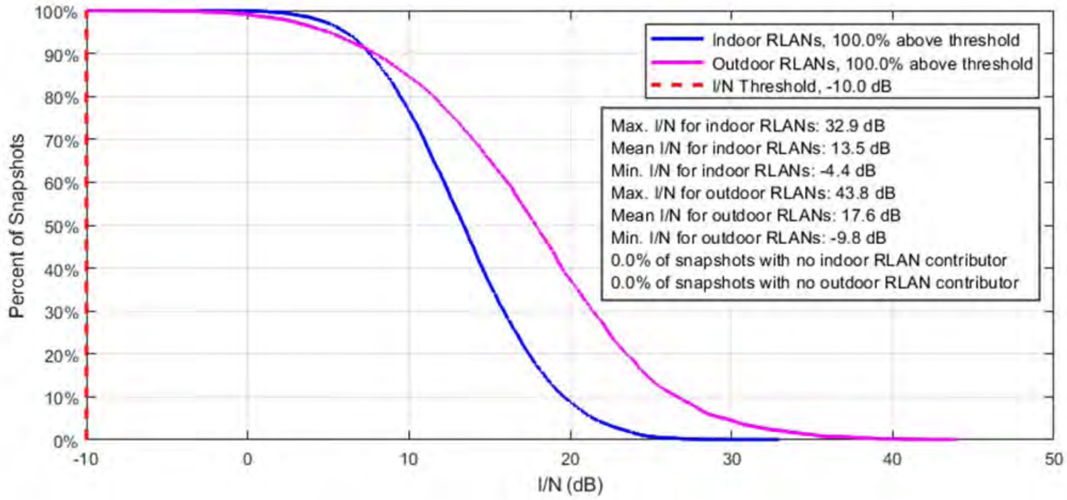

Figure 65. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

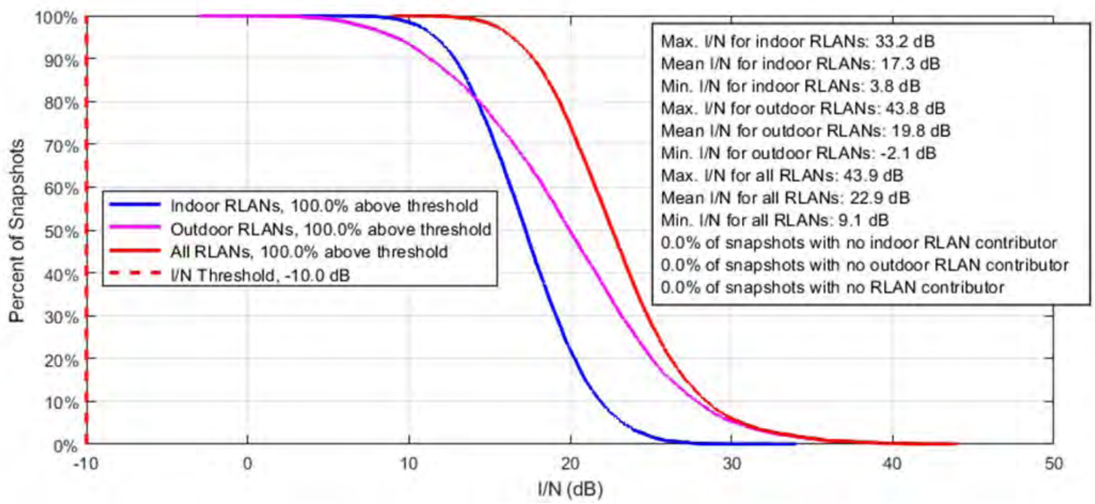

Figure 66. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

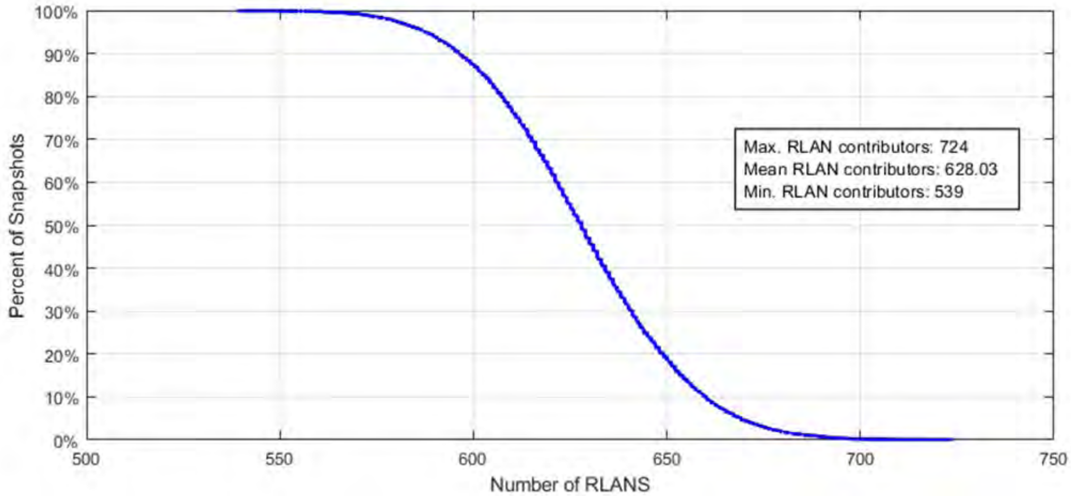

Figure 67. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

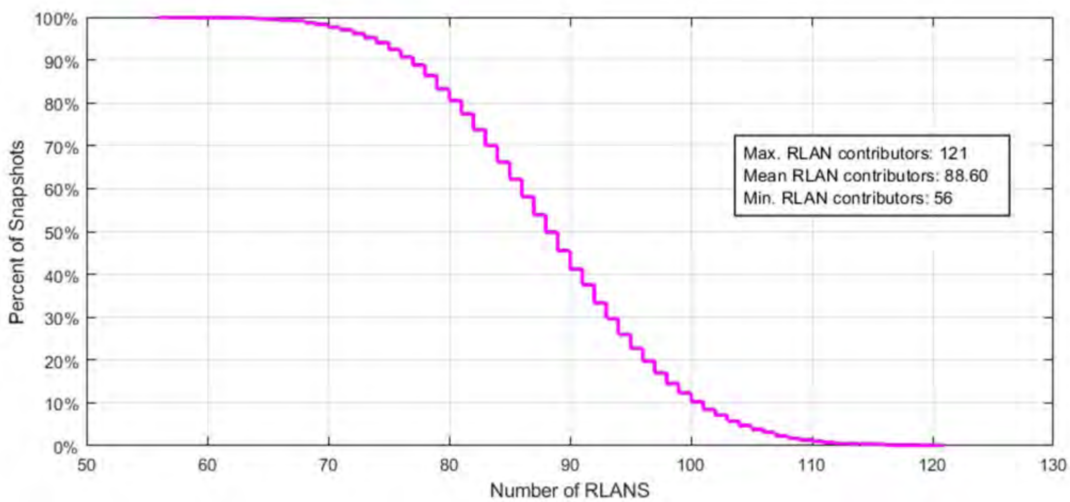

Figure 68. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

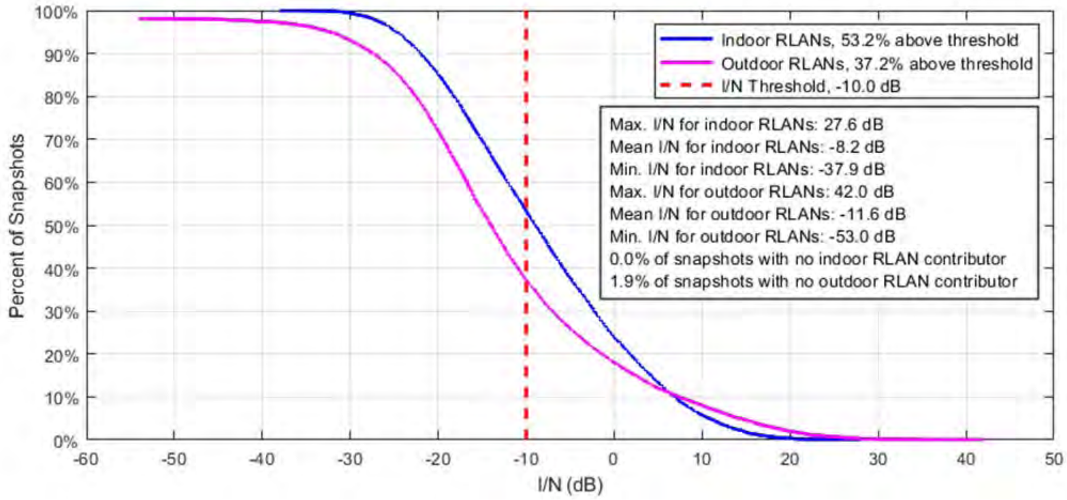

Figure 69. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

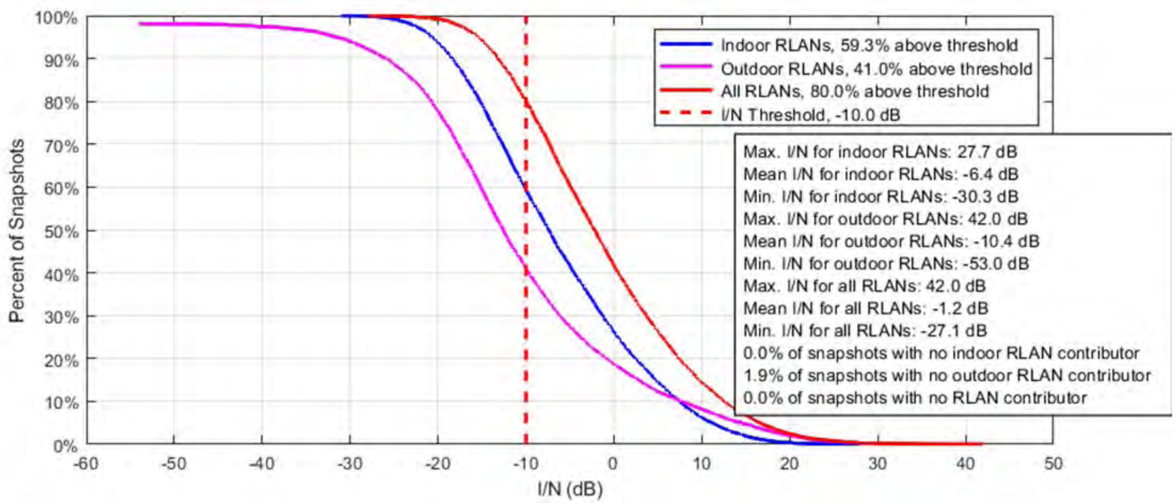

Figure 70. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

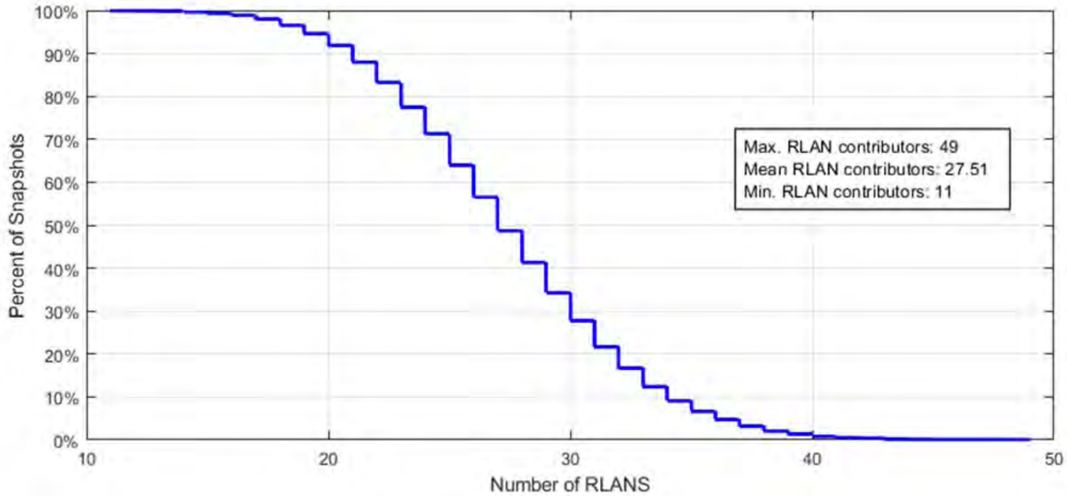

Figure 71. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

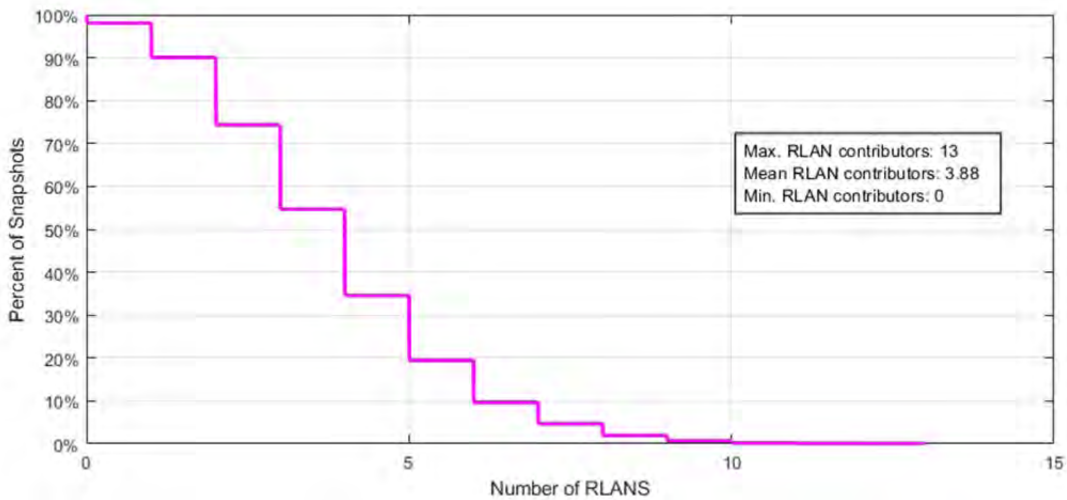

Figure 72. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 94 degrees (toward DC mall ENG truck)

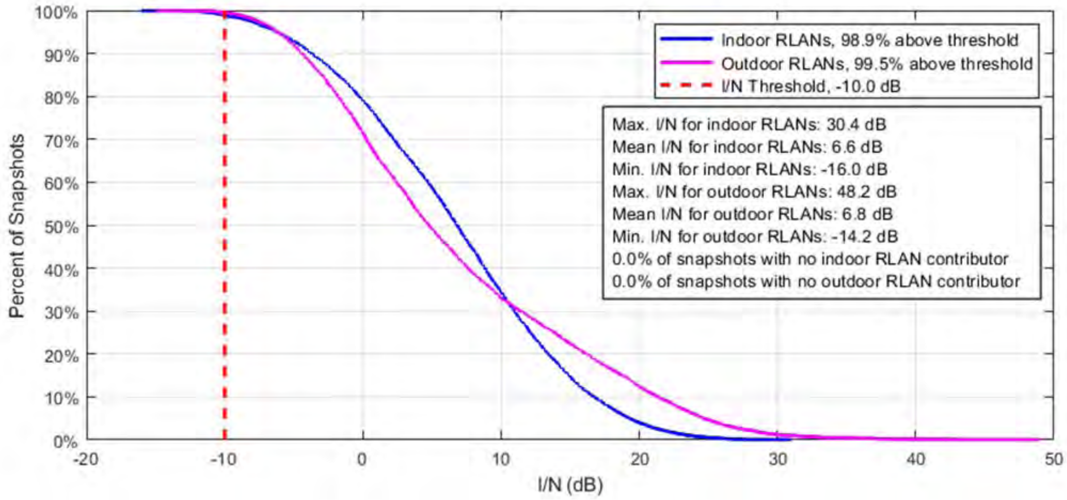

Figure 73. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 315 degrees (random angle)

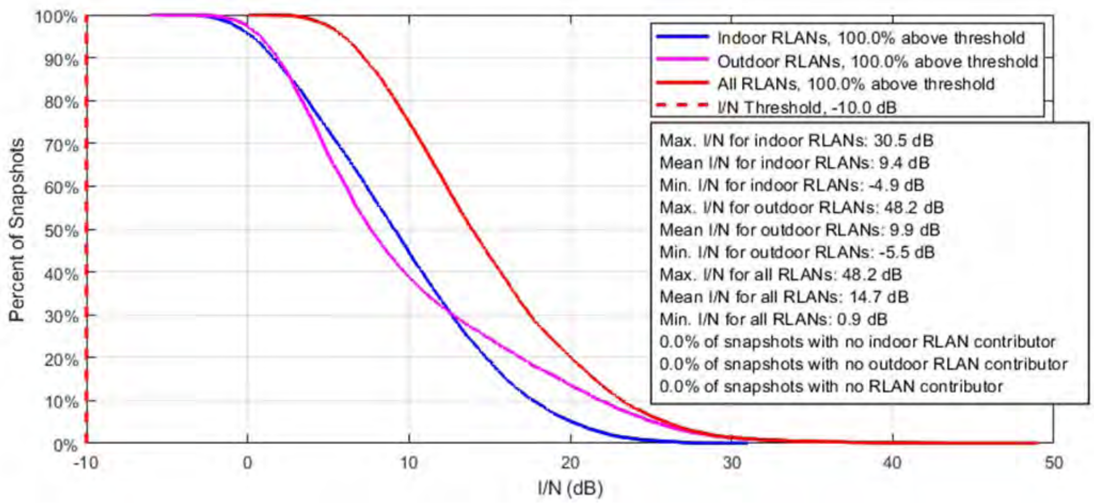

Figure 74. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 315 degrees (random angle)

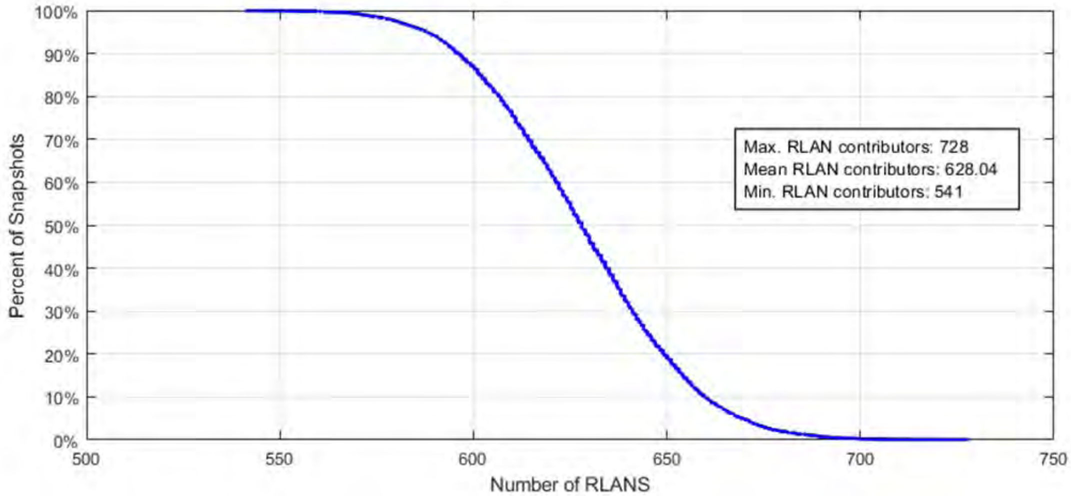

Figure 75. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 315 degrees (random angle)

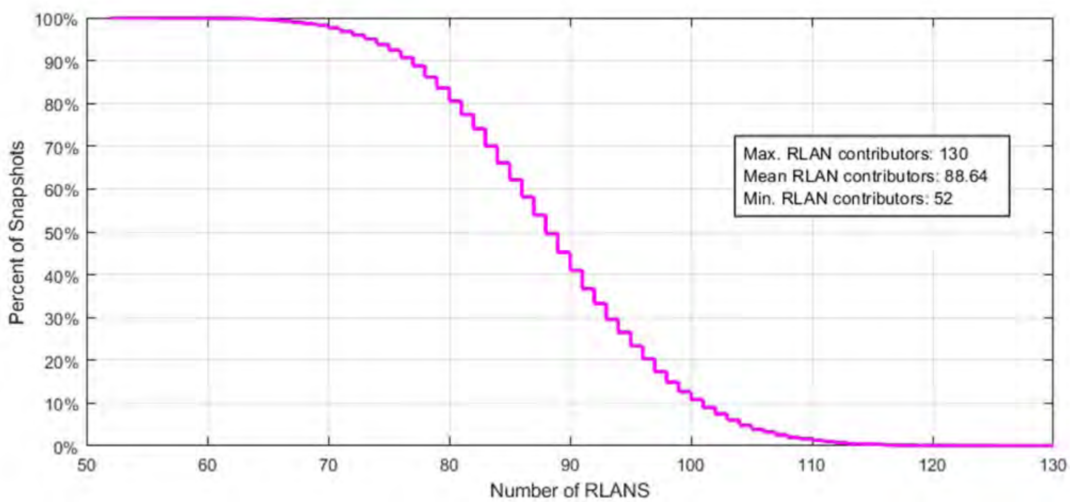

Figure 76. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 315 degrees (random angle)

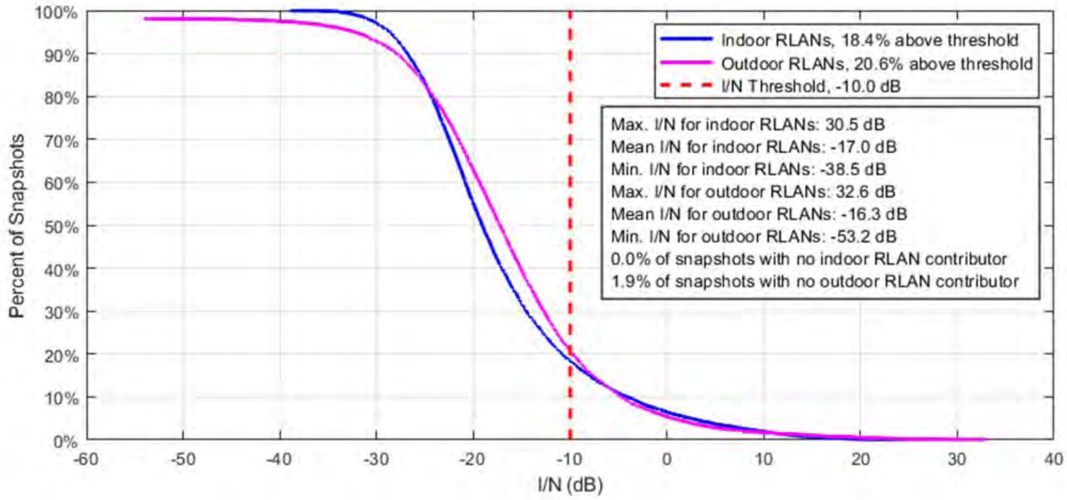

Figure 77. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 315 degrees (random angle)

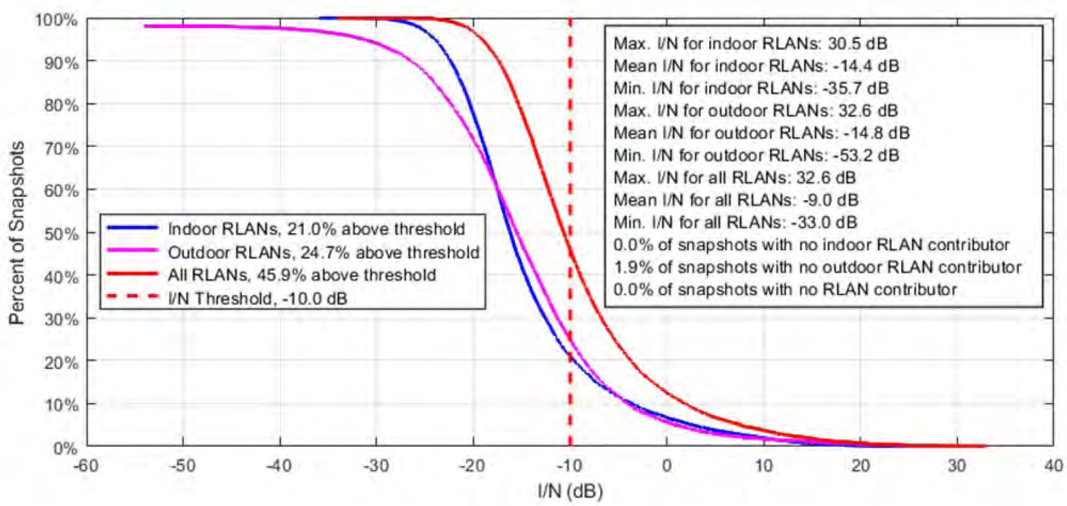

Figure 78. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 315 degrees (random angle)

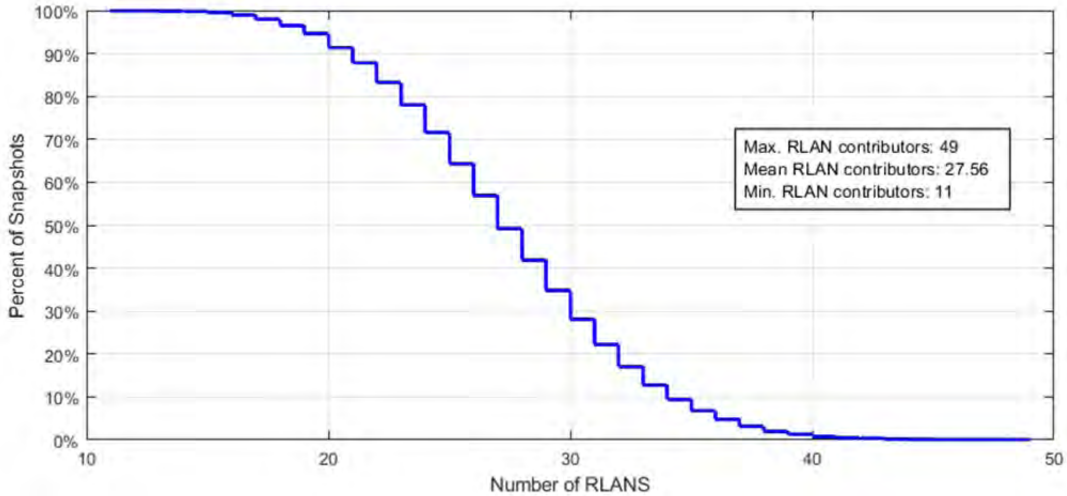

Figure 79. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 315 degrees (random angle)

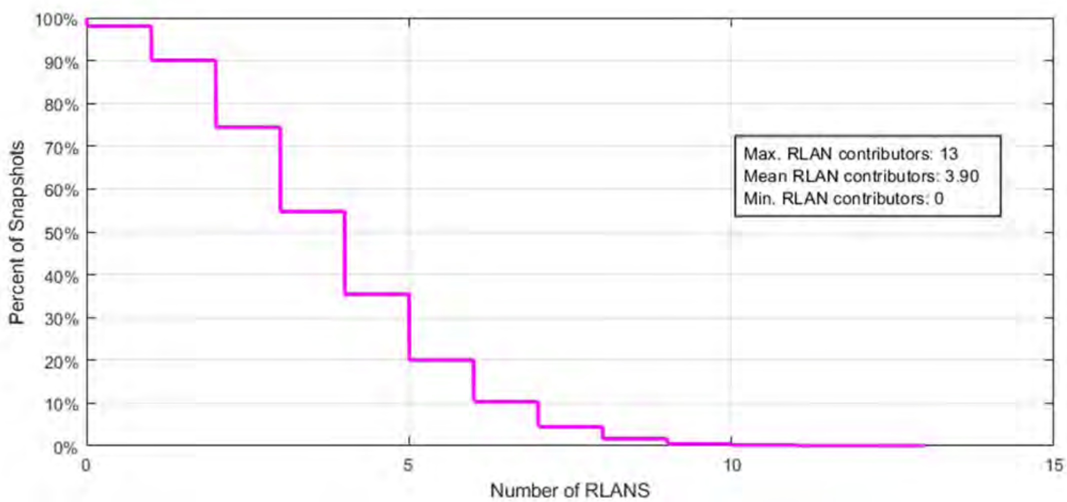

Figure 80. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 315 degrees (random angle)

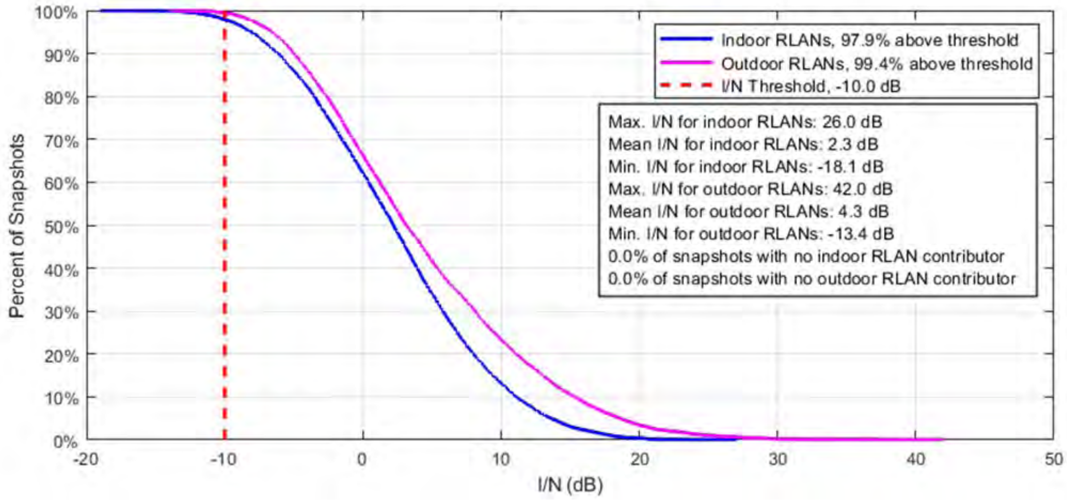

Figure 81. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 180 degrees (random angle)

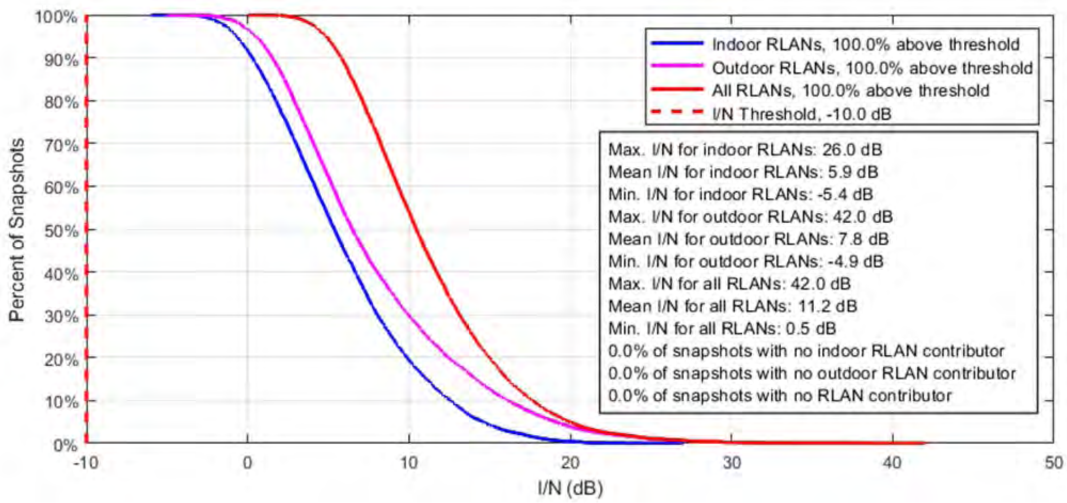

Figure 82. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 10%, antenna azimuth angle = 180 degrees (random angle)

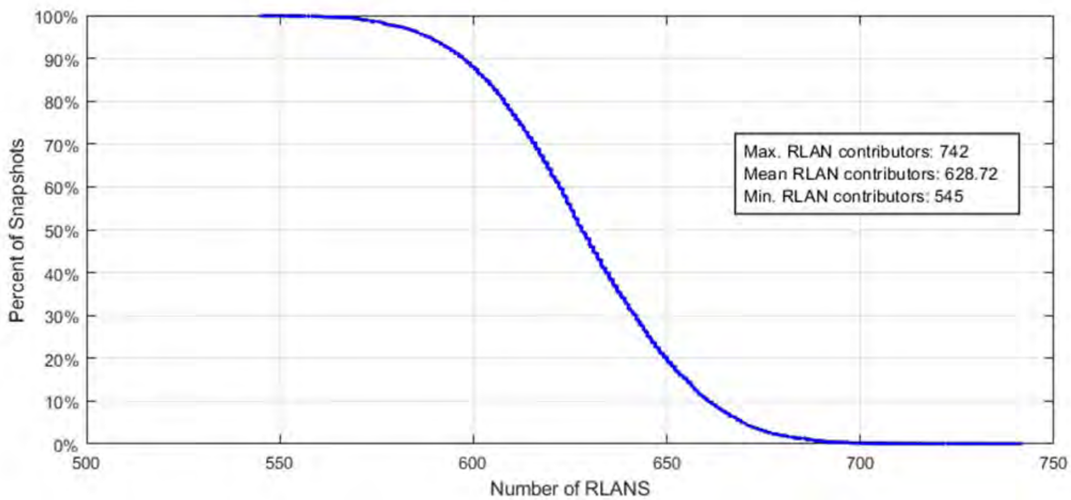

Figure 83. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 180 degrees (random angle)

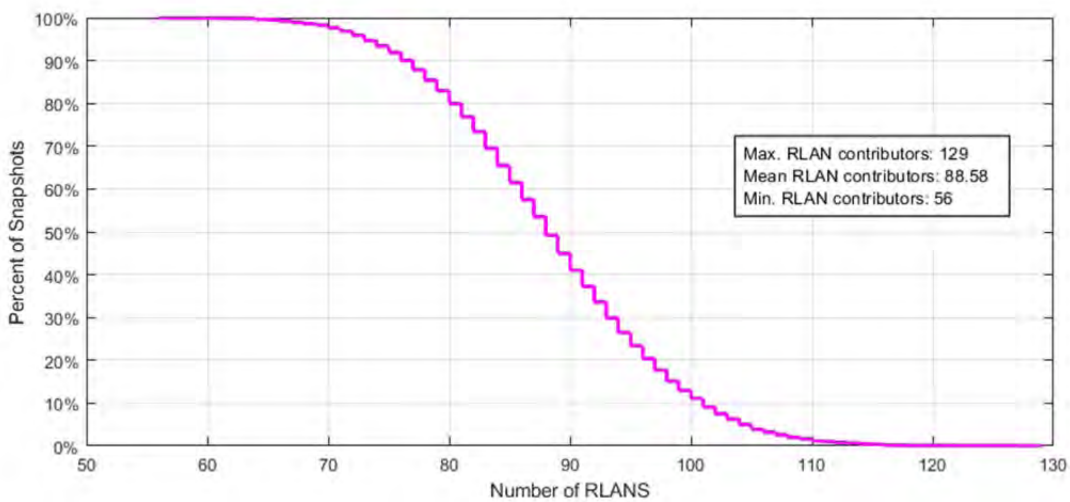

Figure 84. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 10%, antenna azimuth angle = 180 degrees (random angle)

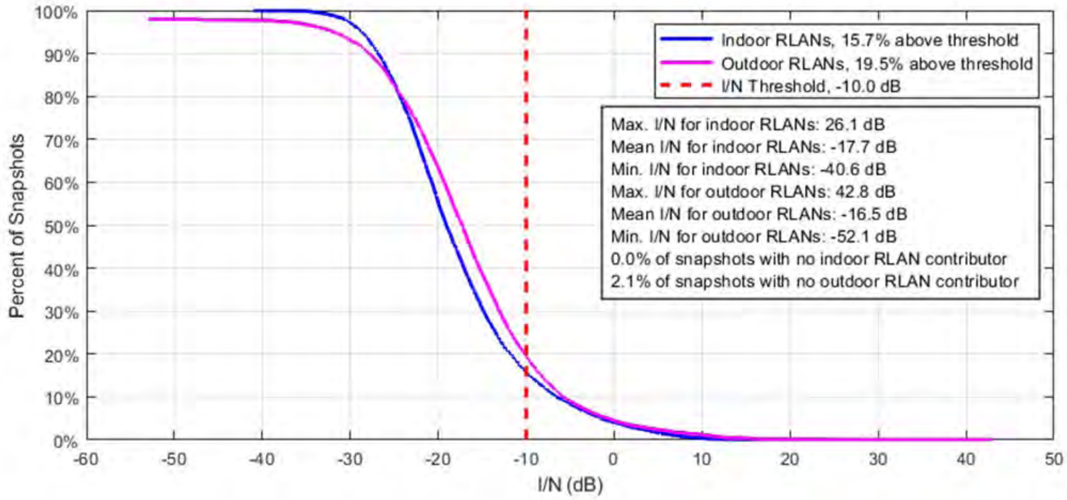

Figure 85. Max. single-entry RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 180 degrees (random angle)

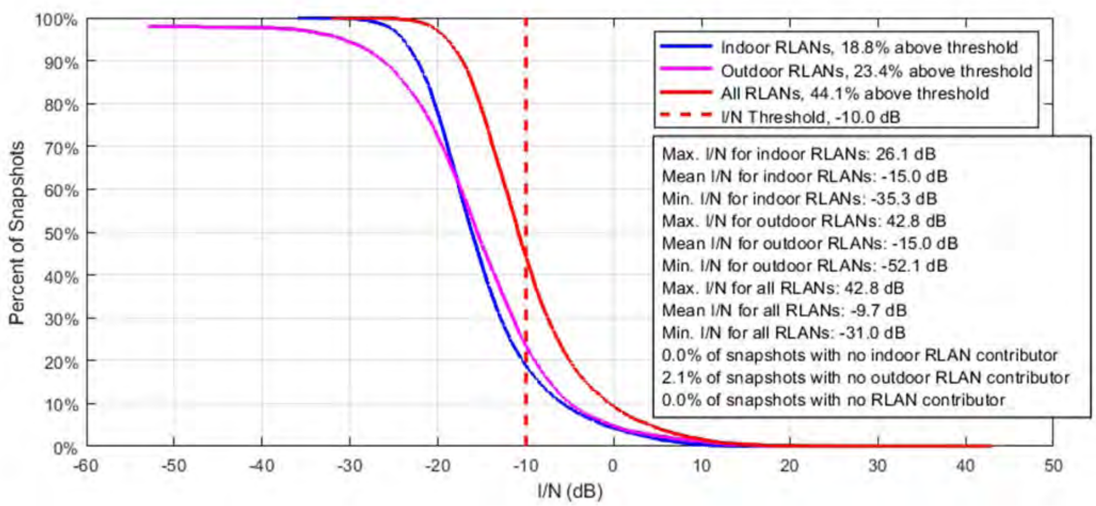

Figure 86. Aggregate RLAN I/N distribution, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 180 degrees (random angle)

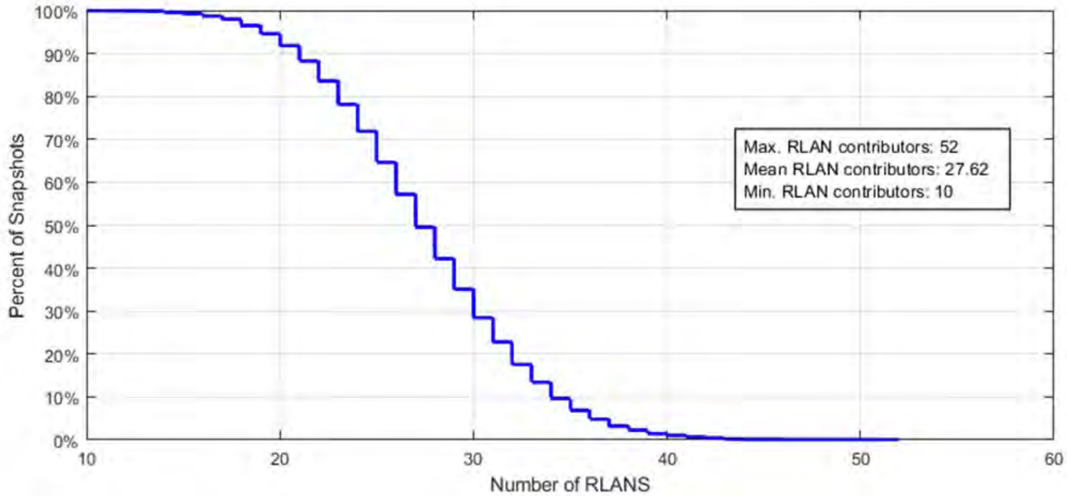

Figure 87. Number of indoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 180 degrees (random angle)

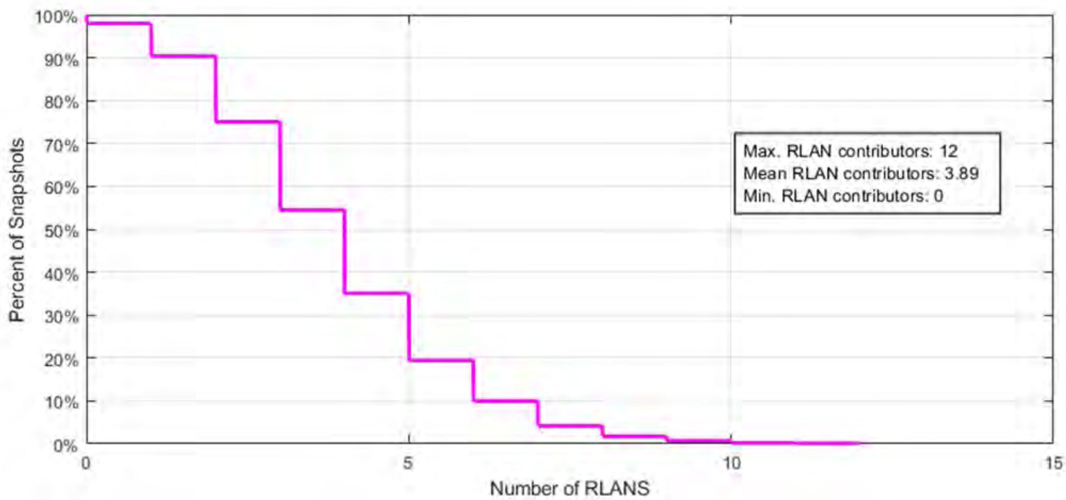

Figure 88. Number of outdoor RLAN contributors per snapshot, DC Old Post Office, activity = 0.44%, antenna azimuth angle = 180 degrees (random angle)

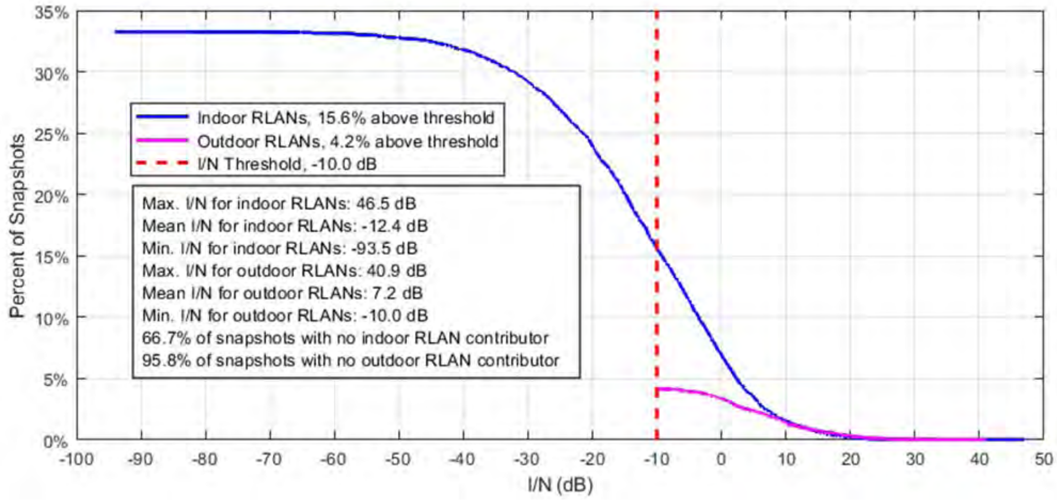

Figure 89. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

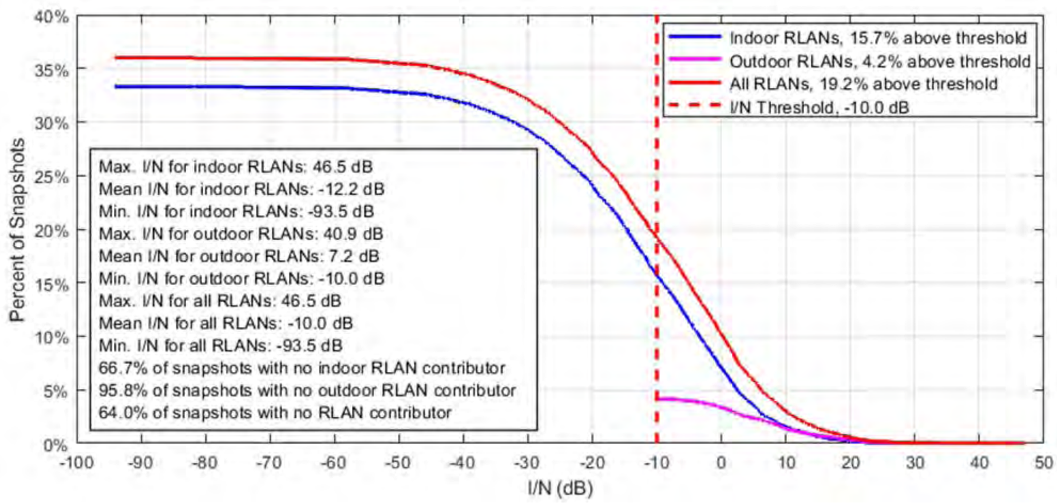

Figure 90. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

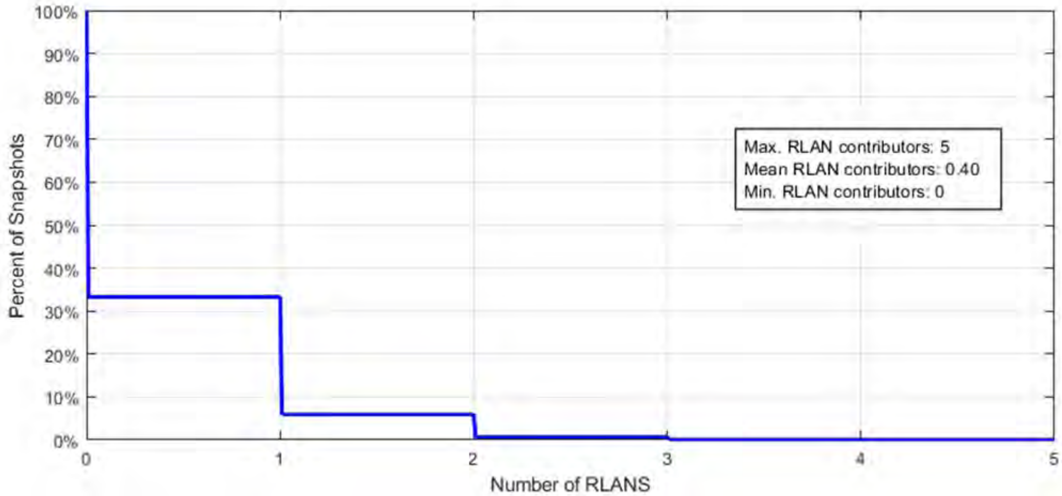

Figure 91. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

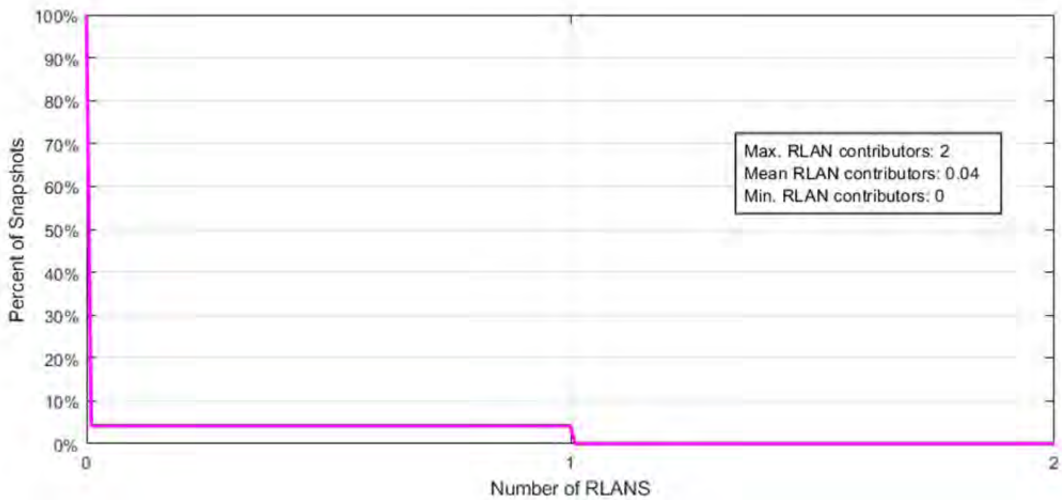

Figure 92. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

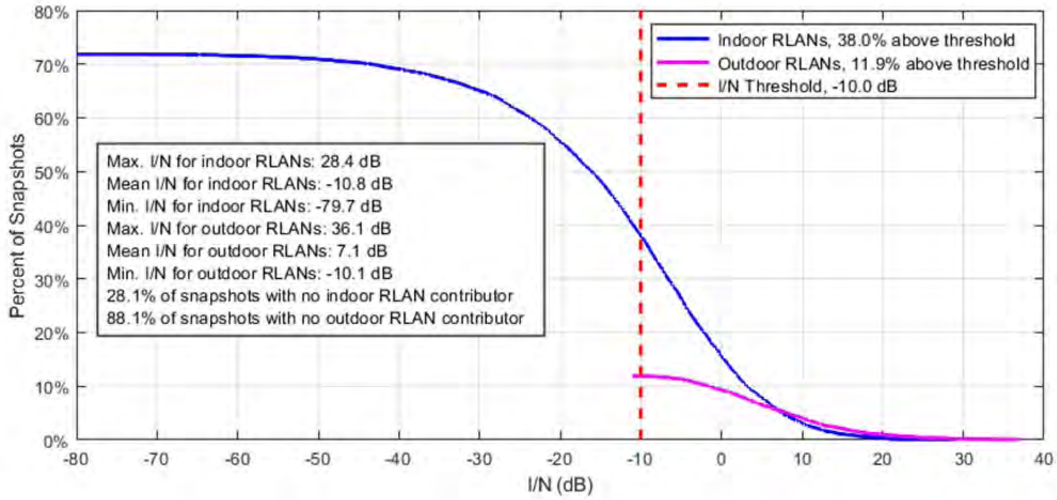

Figure 93. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 15 m height

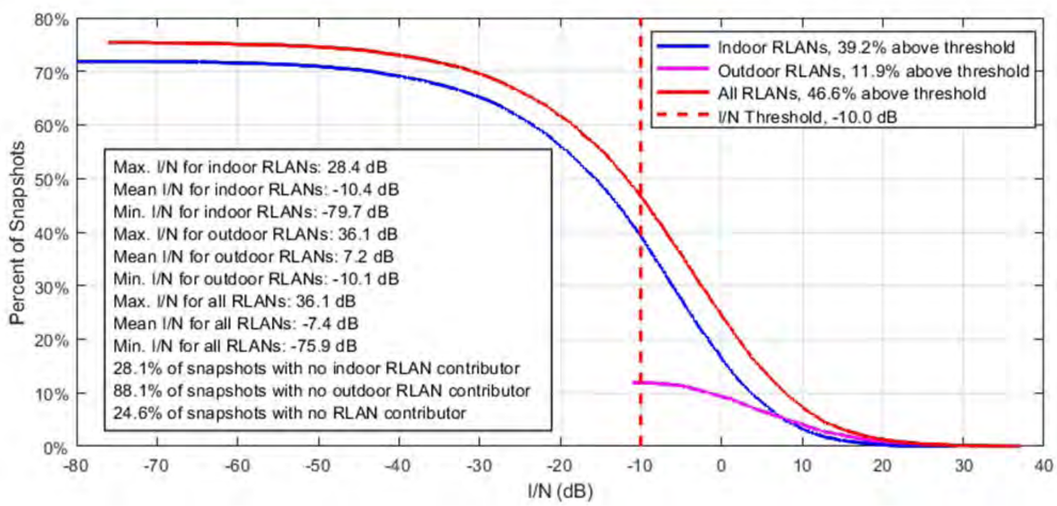

Figure 94. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 15 m height

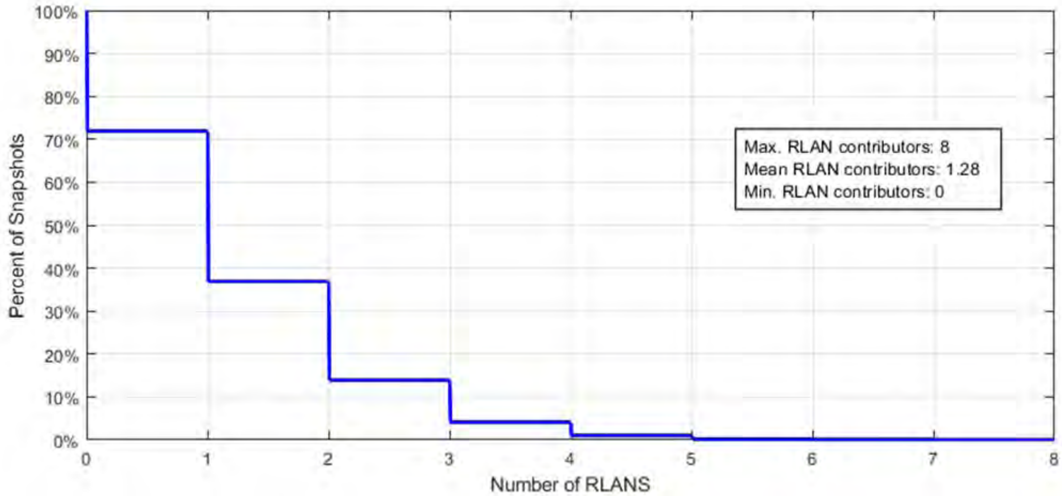

Figure 95. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 15 m height

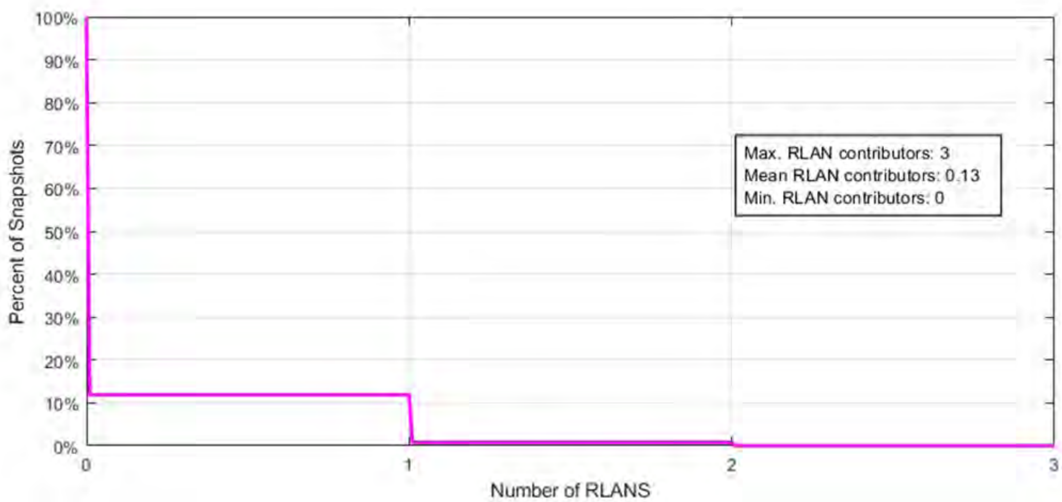

Figure 96. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, omnidirectional antenna at 15 m height

Note: For the DC Mall ENG truck case with 0.44% activity and a 1.5 m antenna height, there were no active/LOS RLAN contributors for 10,000 Monte Carlo model snapshots. Therefore, EMI is unlikely for this case.

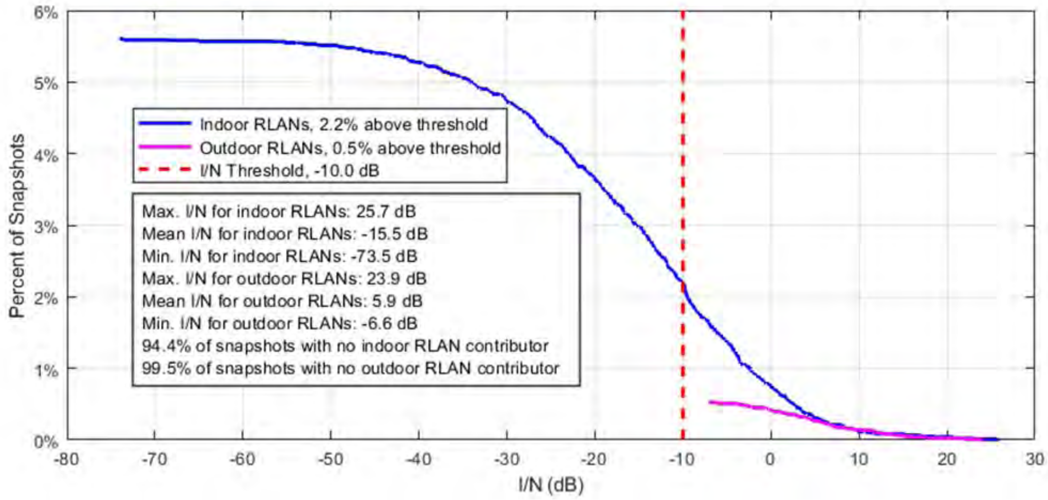

Figure 97. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

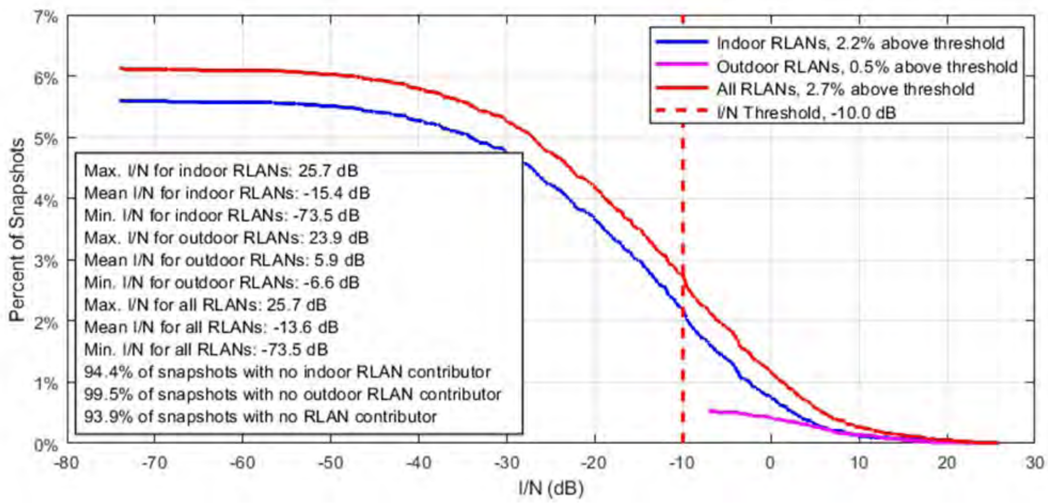

Figure 98. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

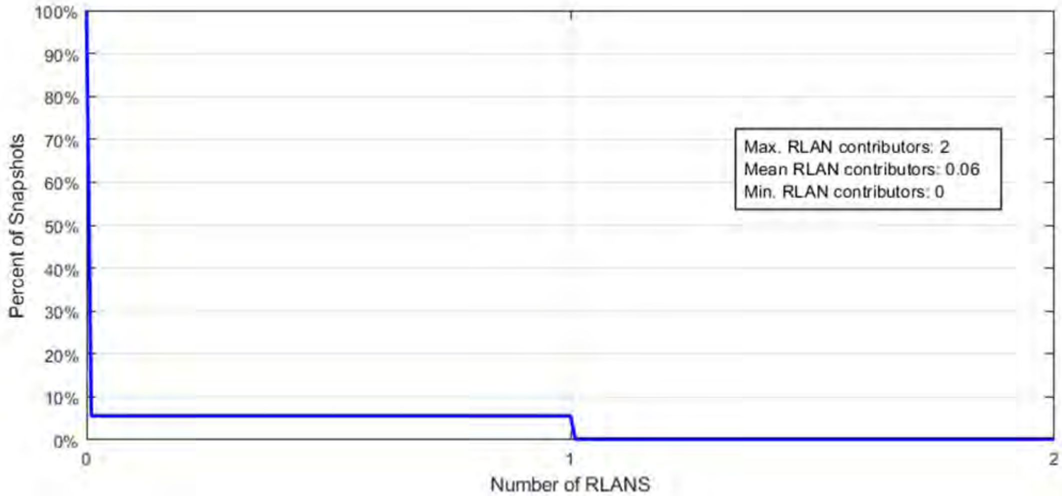

Figure 99. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

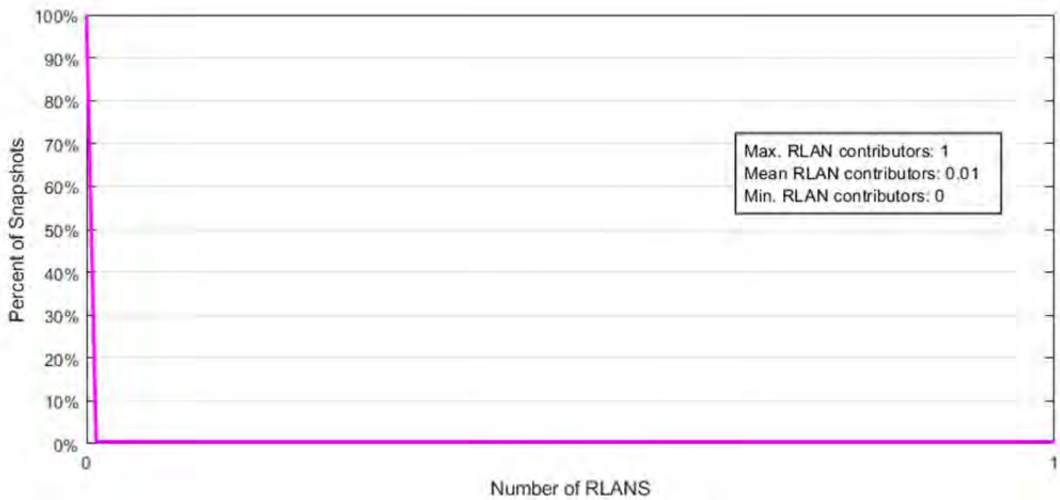

Figure 100. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

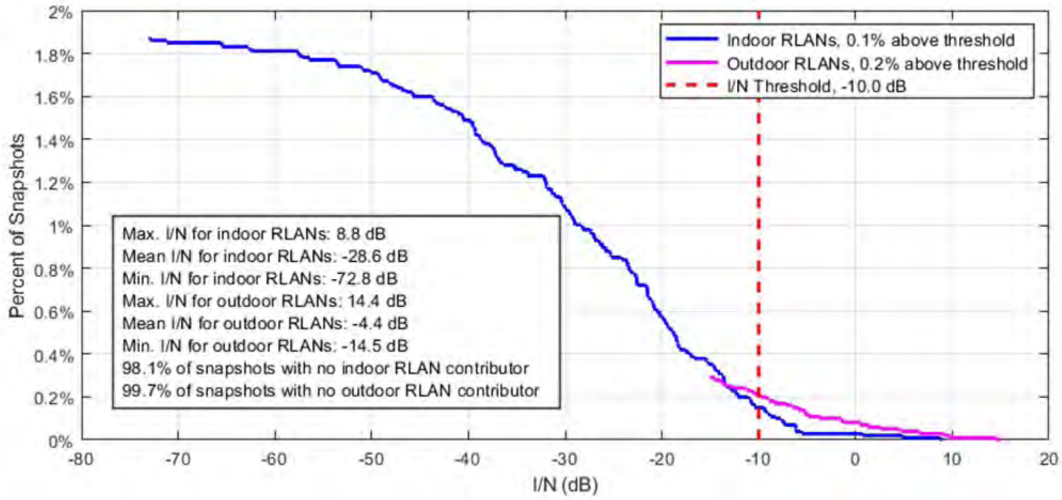

Figure 101. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

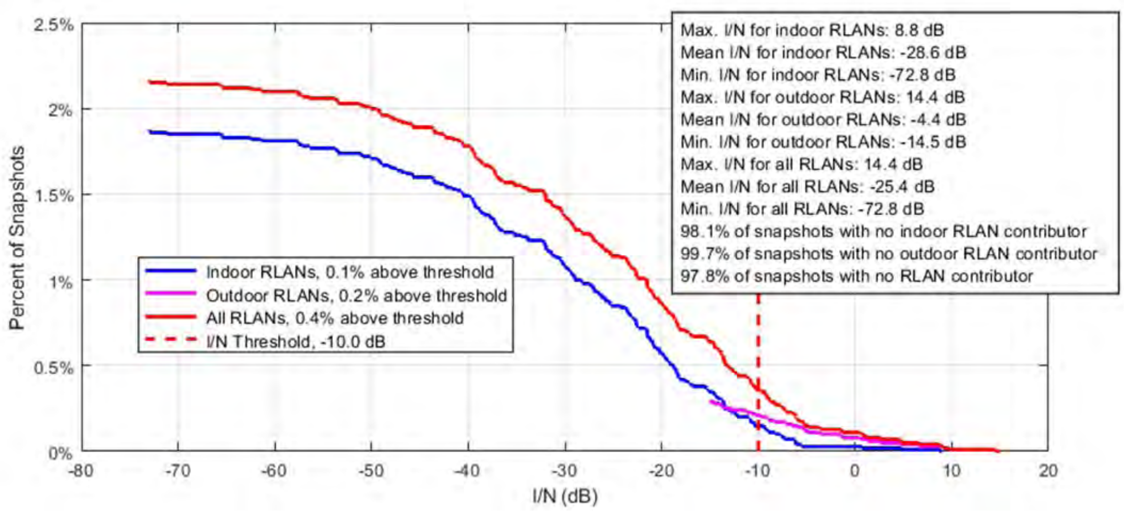

Figure 102. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

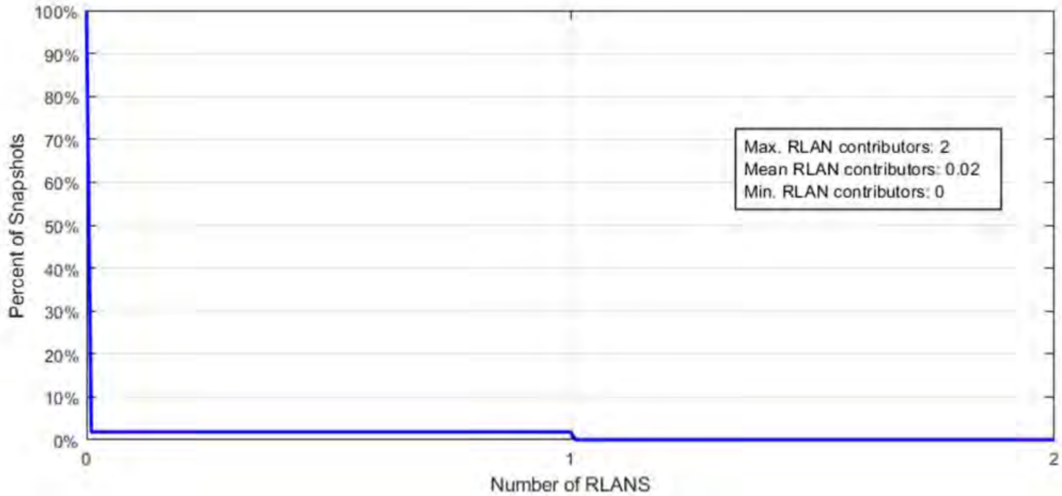

Figure 103. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

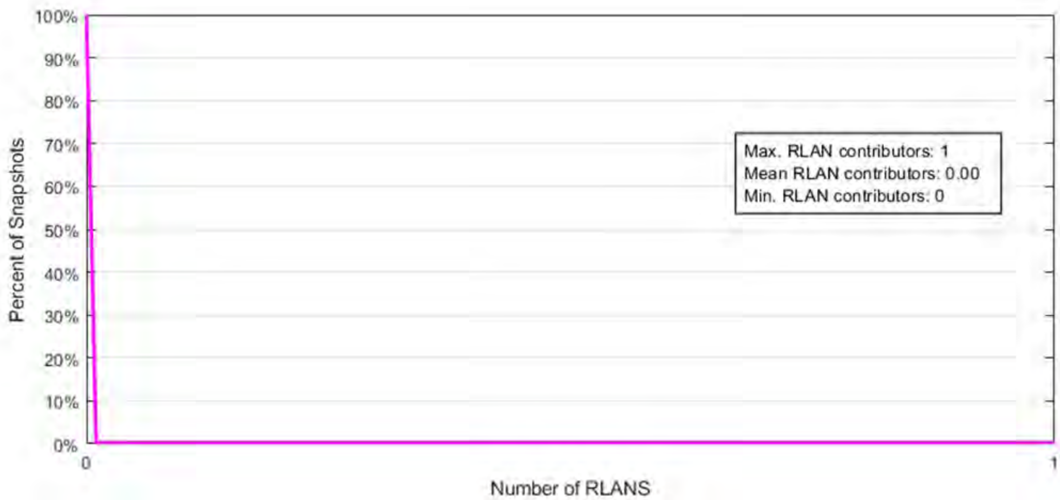

Figure 104. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 1.5 m height

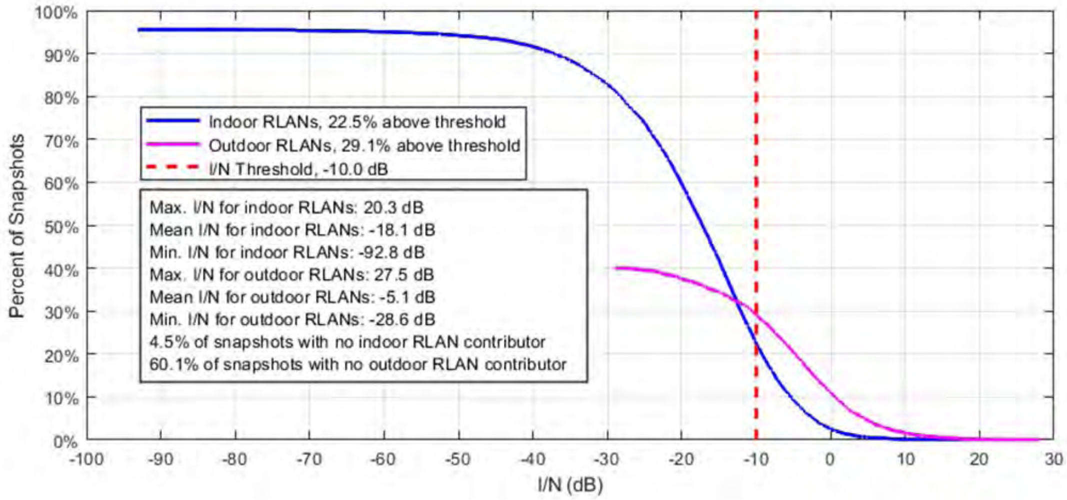

Figure 105. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 15 m height

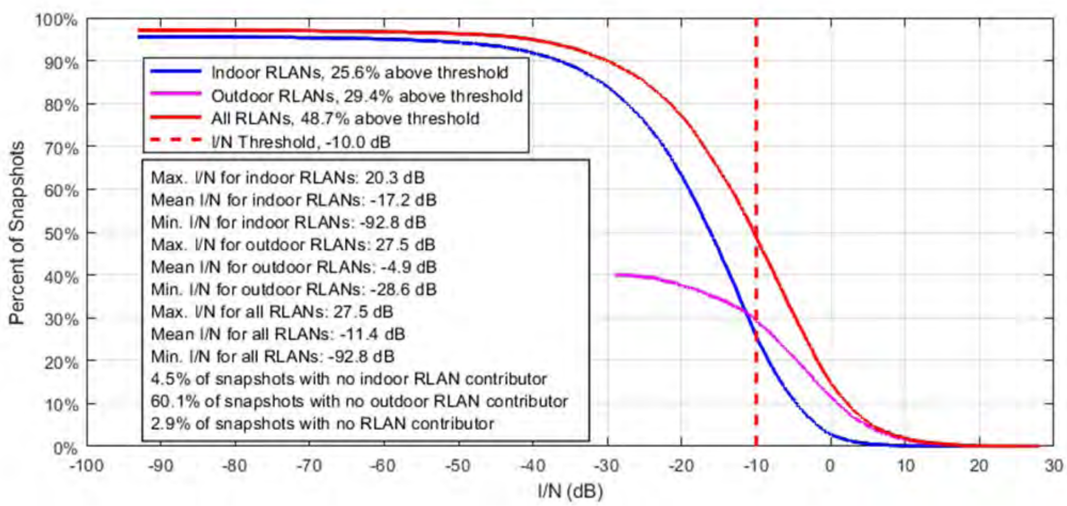

Figure 106. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 15 m height

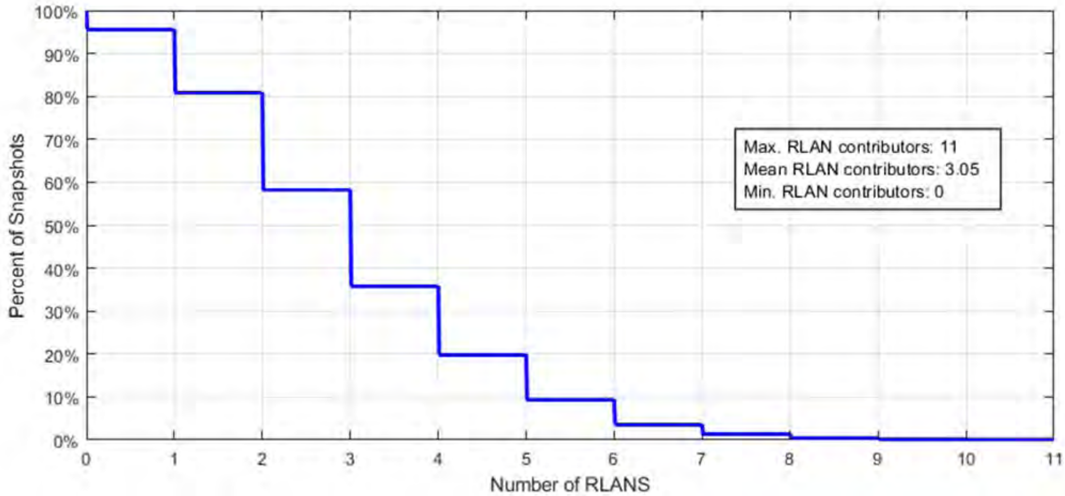

Figure 107. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 15 m height

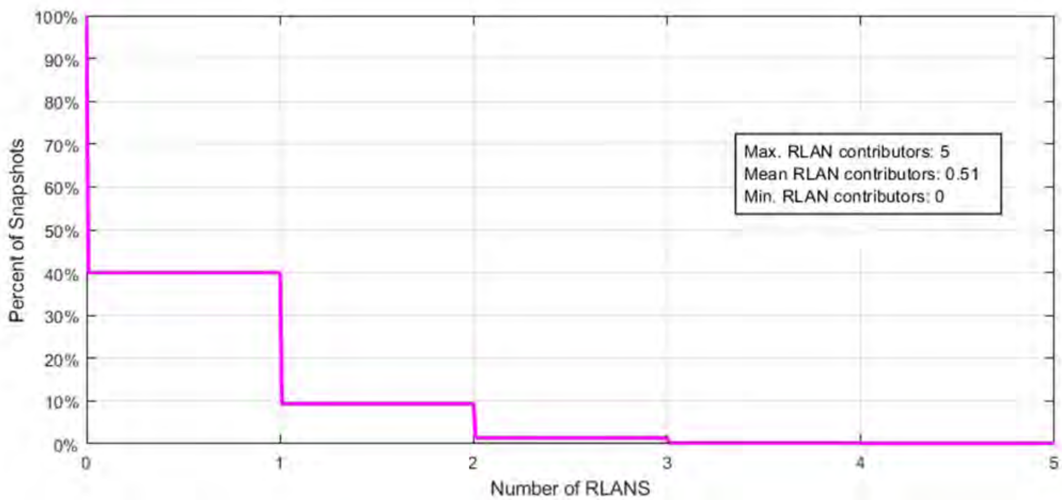

Figure 108. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, omnidirectional antenna at 15 m height

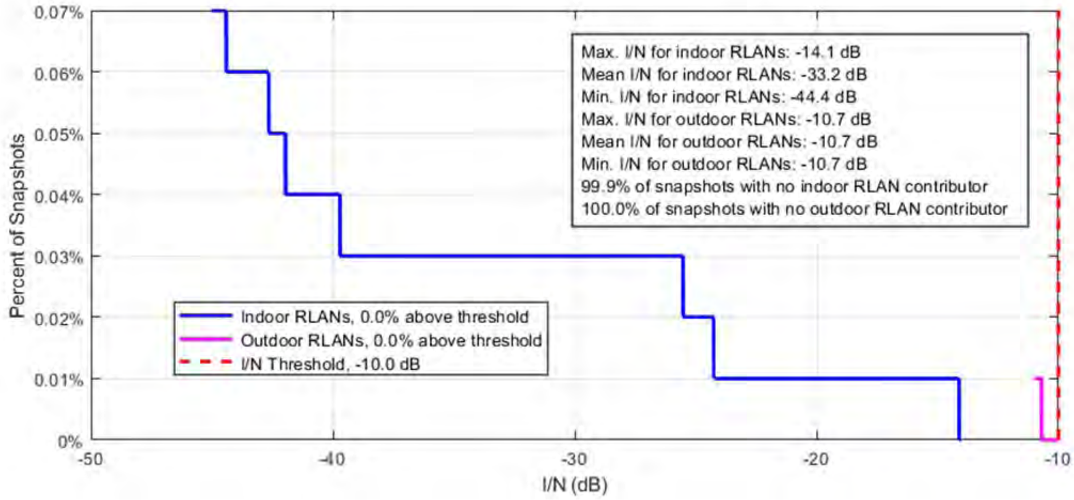

Figure 109. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 1.5 m height

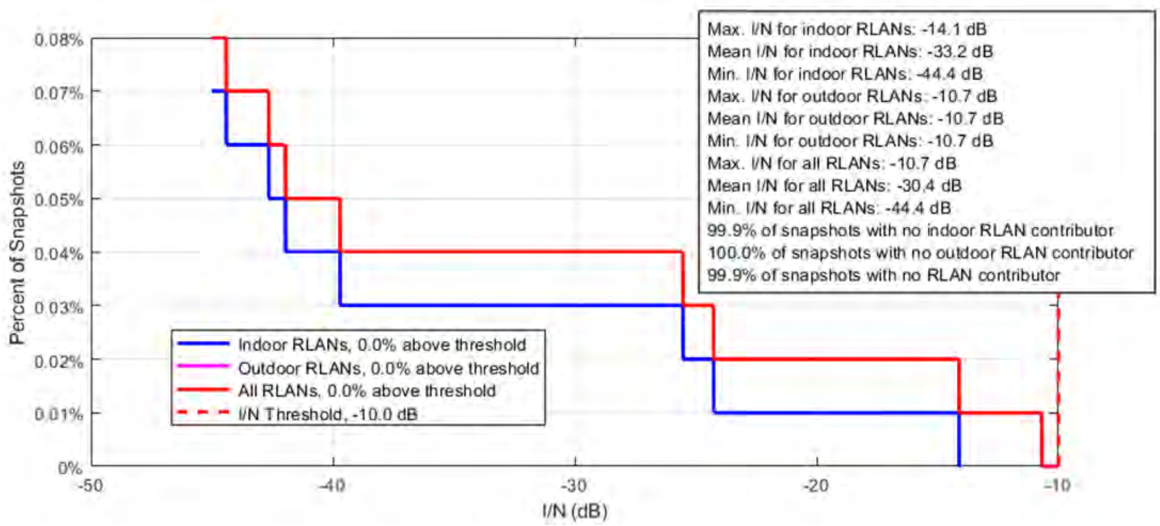

Figure 110. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 1.5 m height

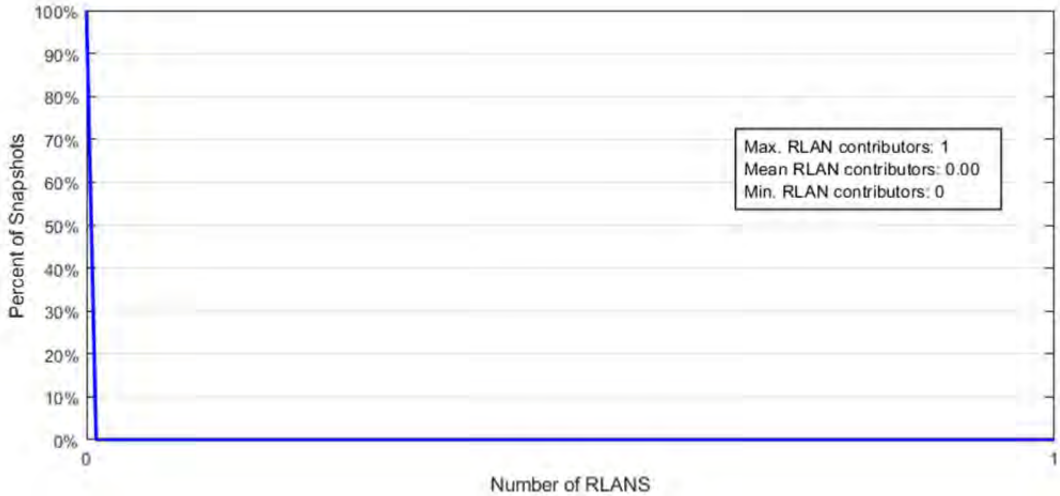

Figure 111. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 1.5 m height

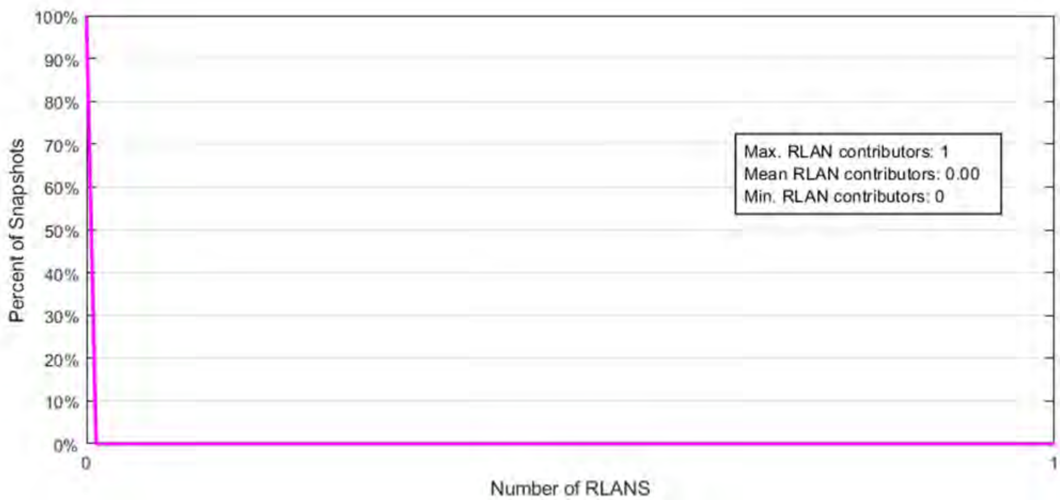

Figure 112. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 1.5 m height

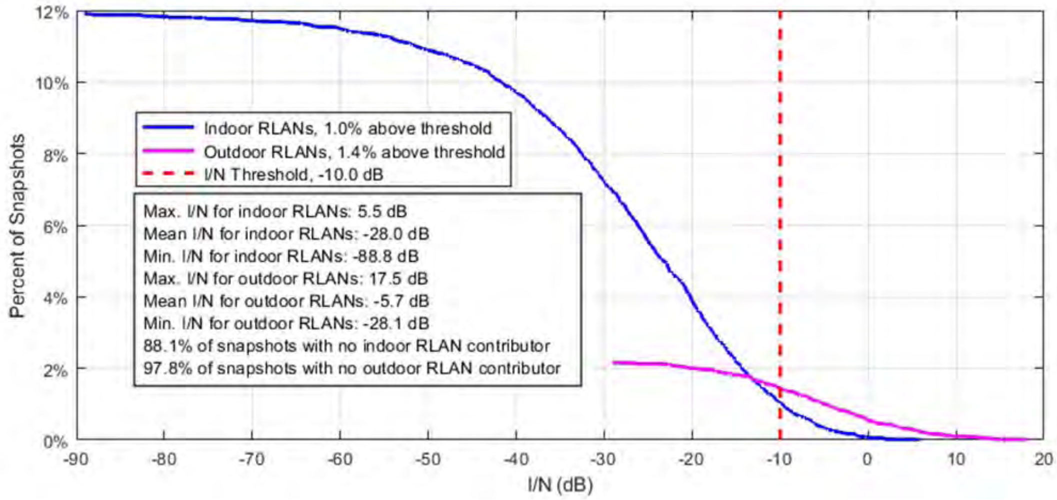

Figure 113. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

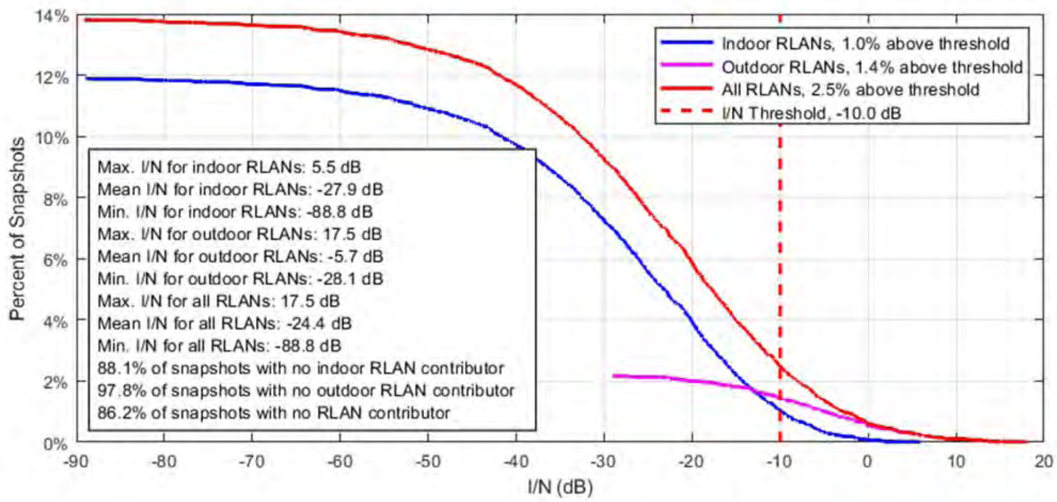

Figure 114. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

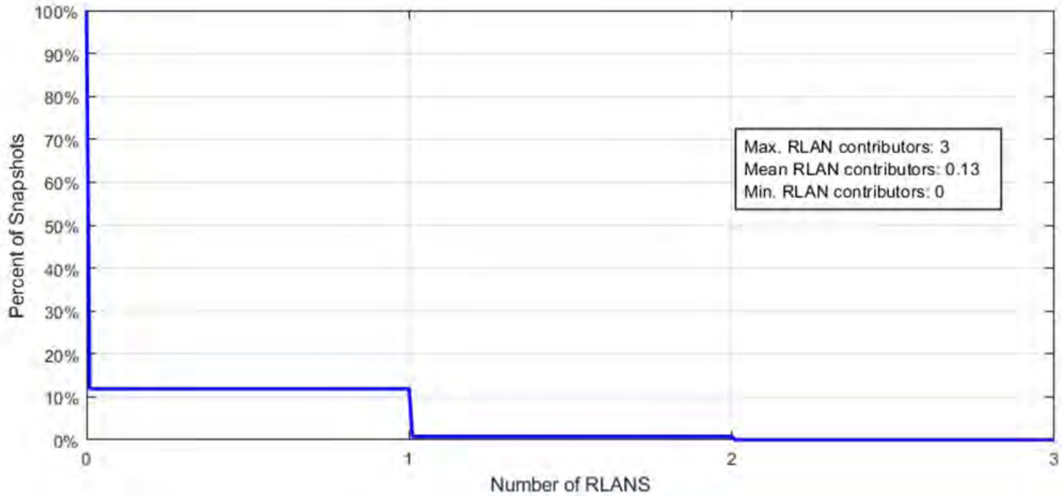

Figure 115. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

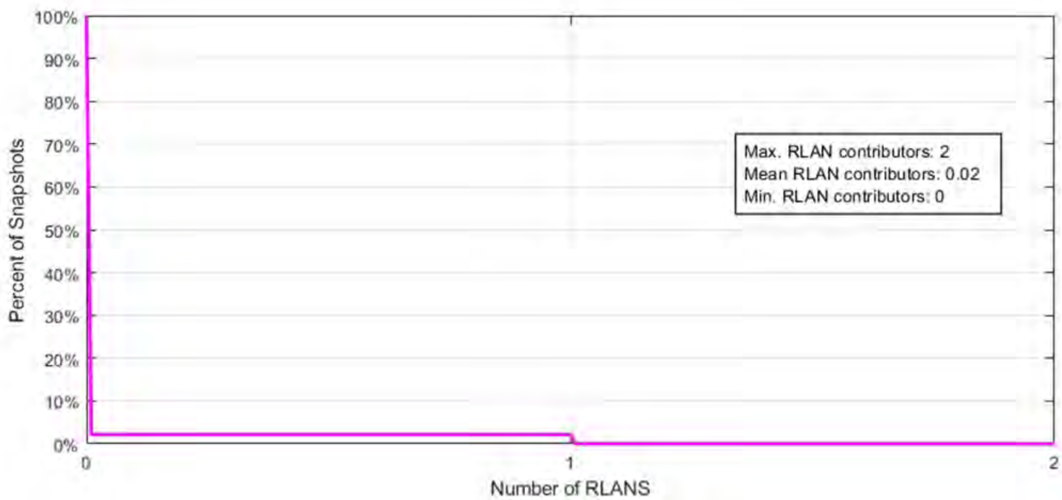

Figure 116. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, omnidirectional antenna at 15 m height

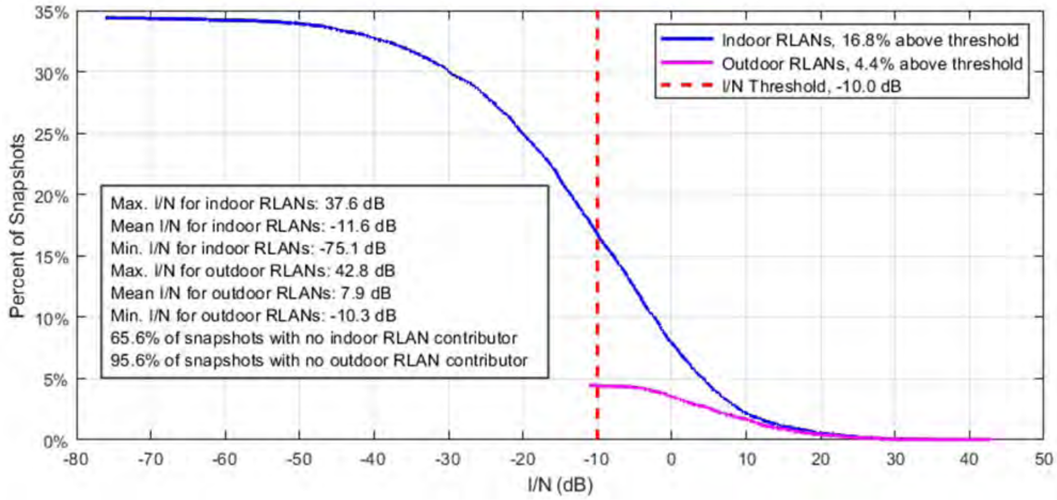

Figure 117. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

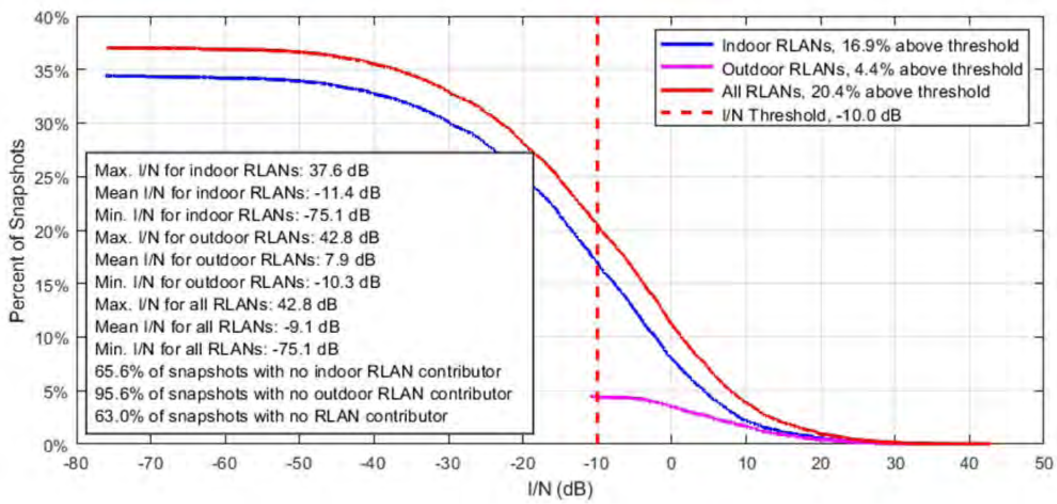

Figure 118. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

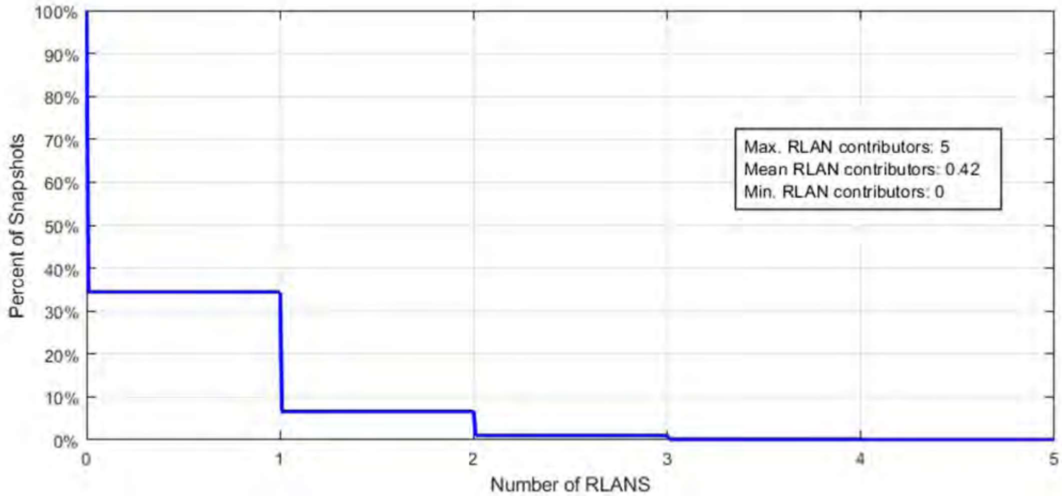

Figure 119. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

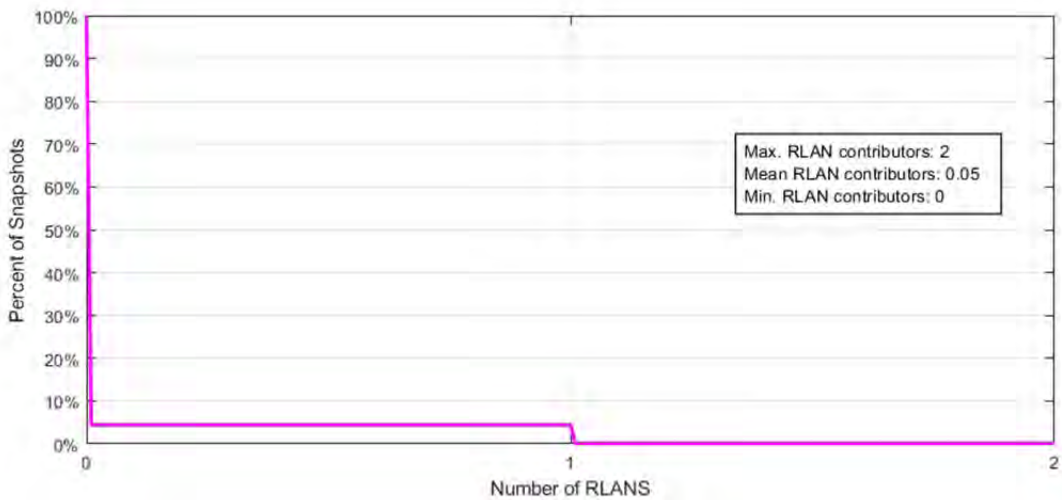

Figure 120. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

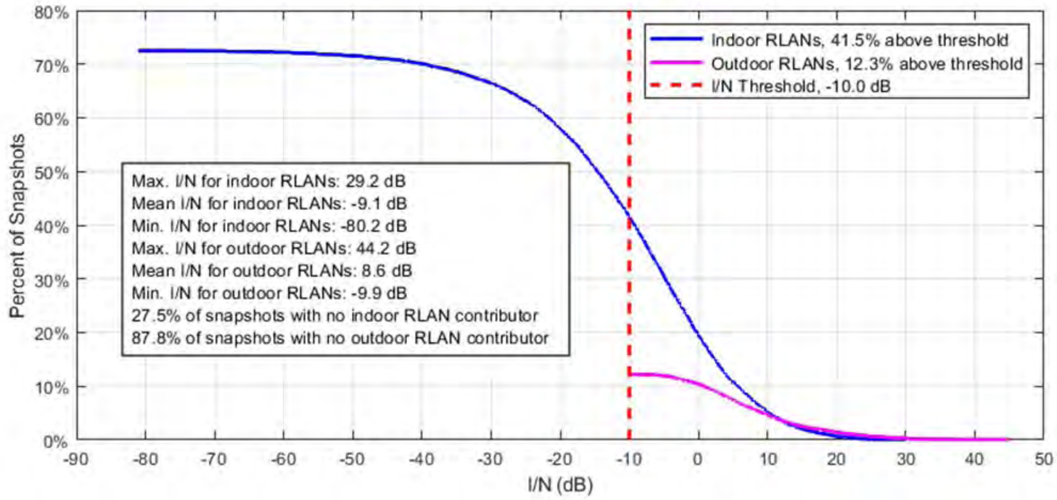

Figure 121. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

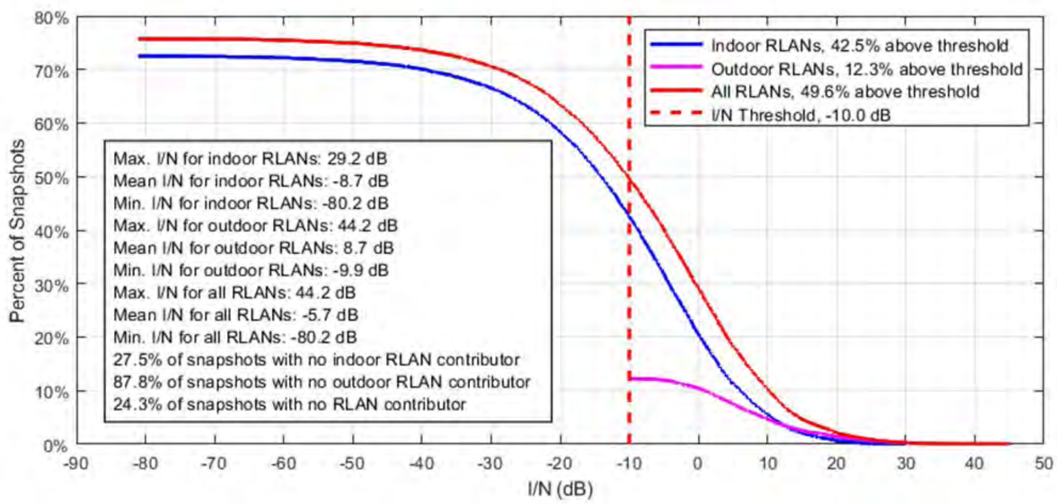

Figure 122. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

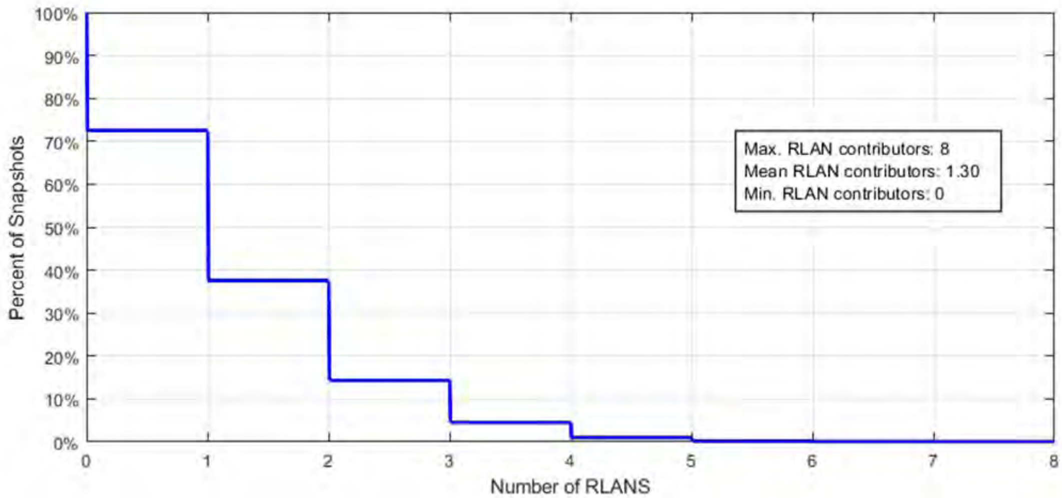

Figure 123. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

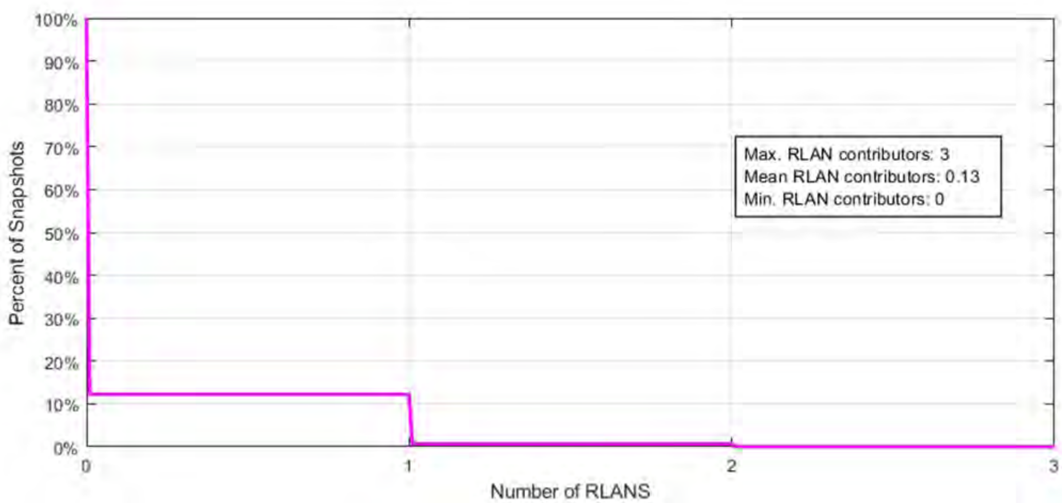

Figure 124. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

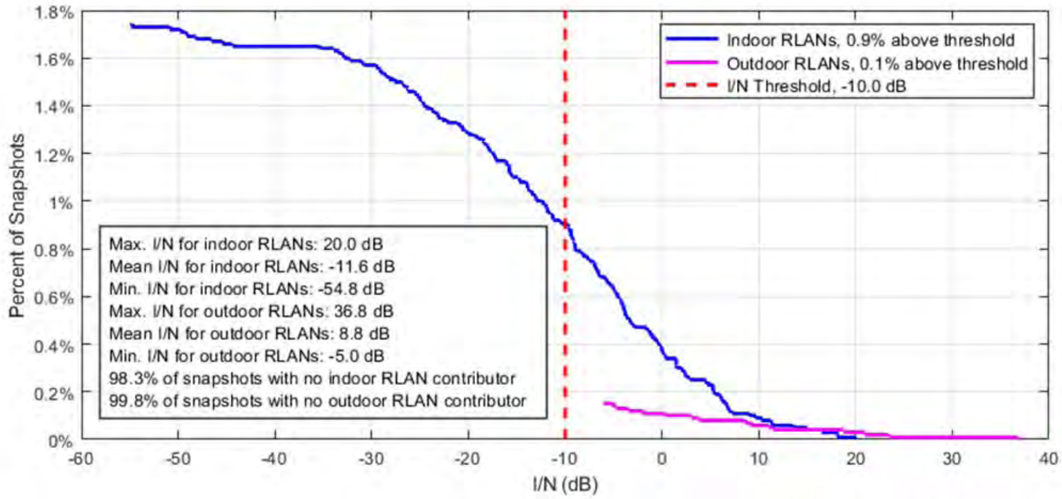

Figure 125. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

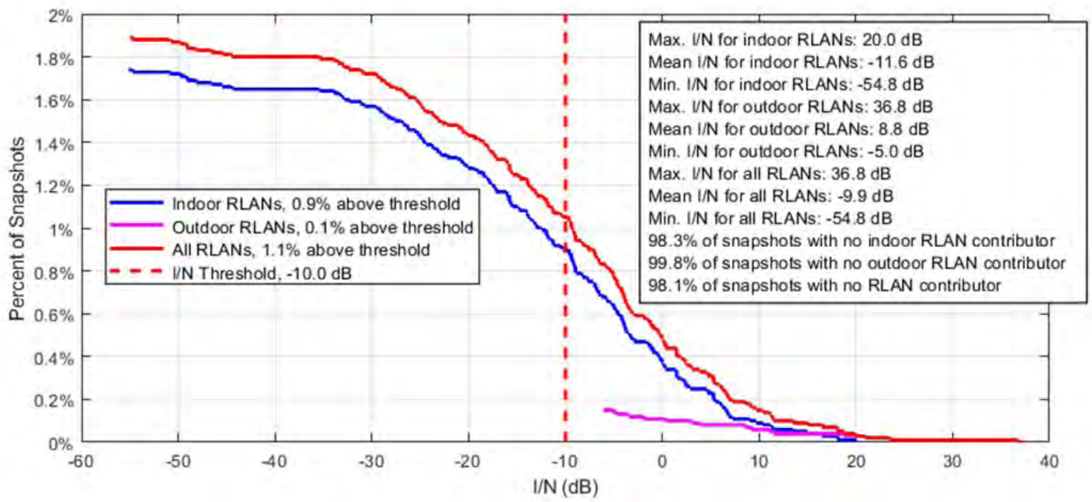

Figure 126. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

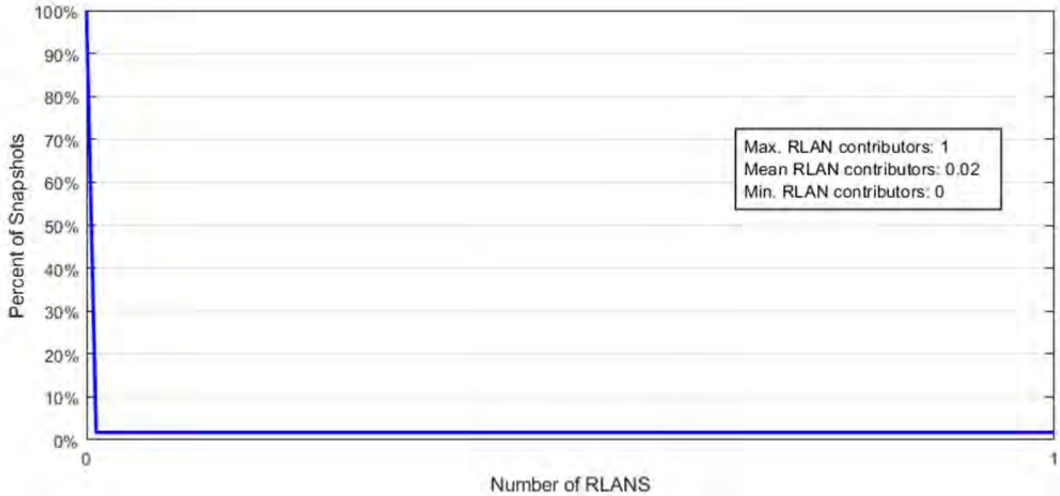

Figure 127. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

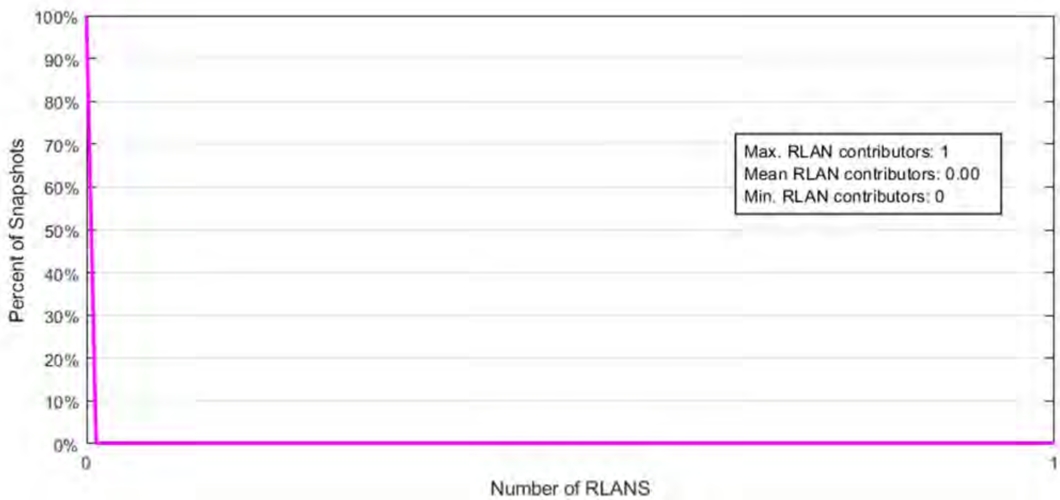

Figure 128. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

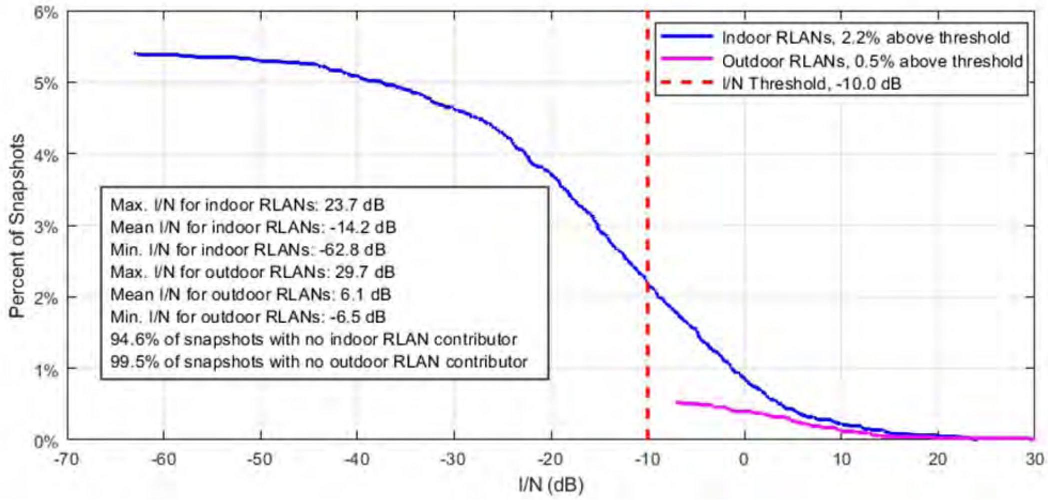

Figure 129. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

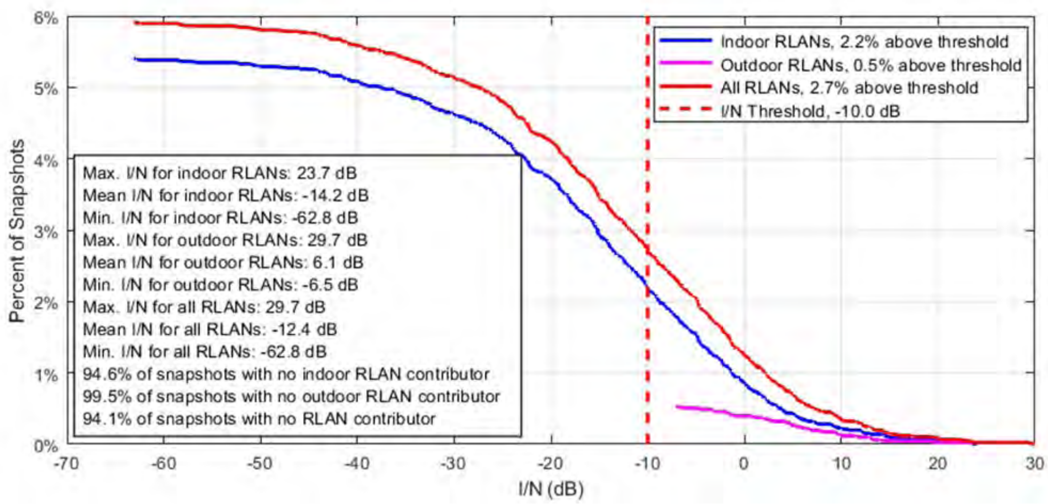

Figure 130. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

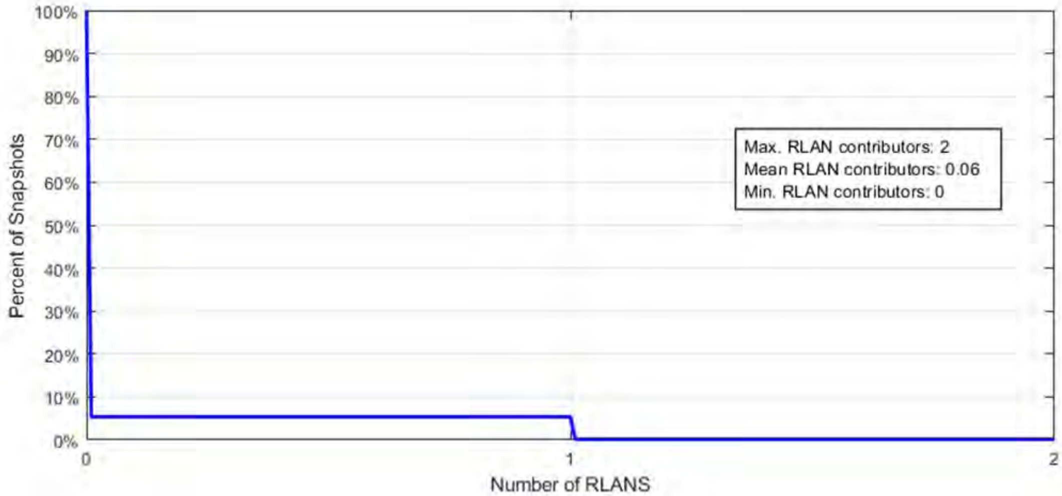

Figure 131. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

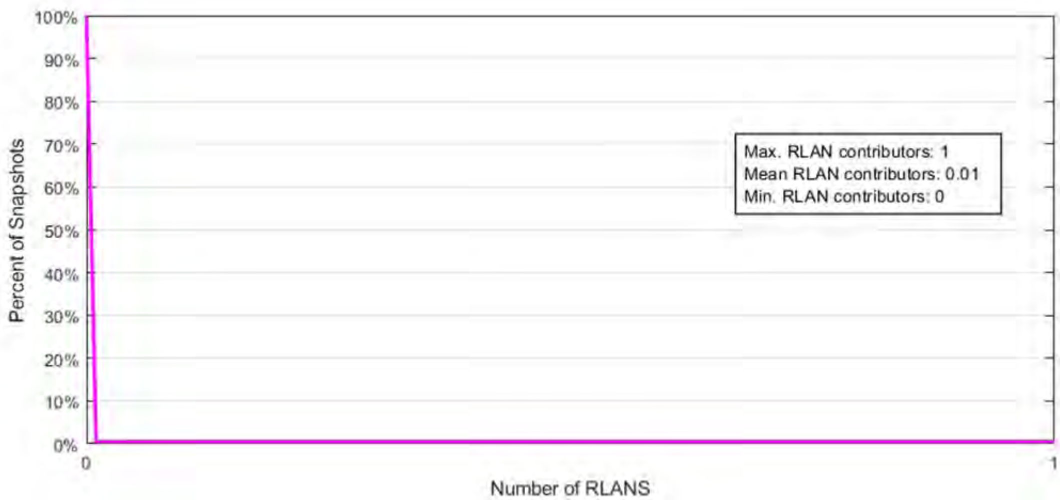

Figure 132. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

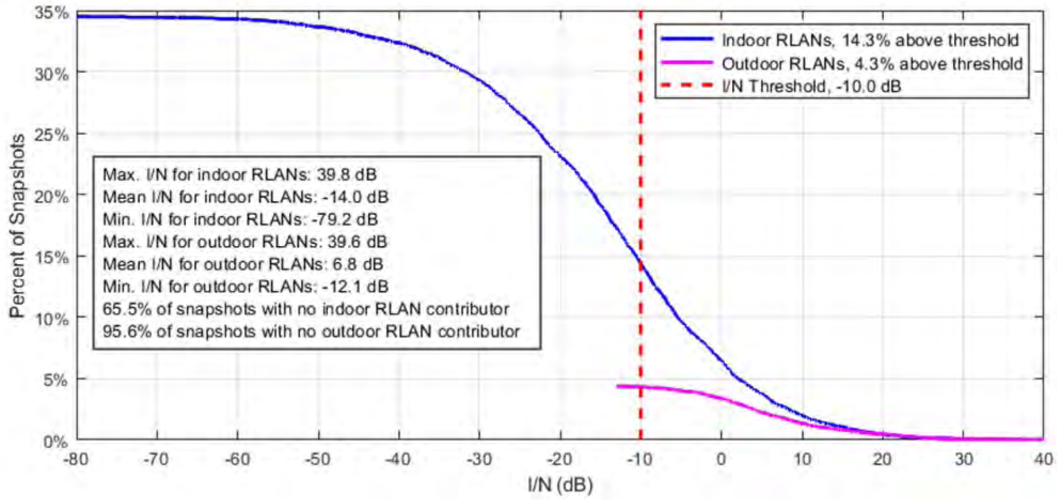

Figure 133. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

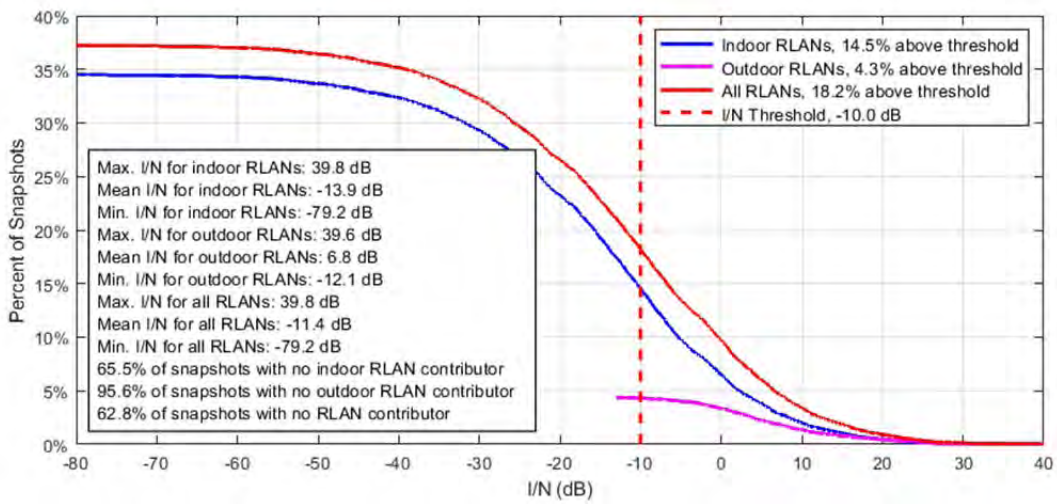

Figure 134. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

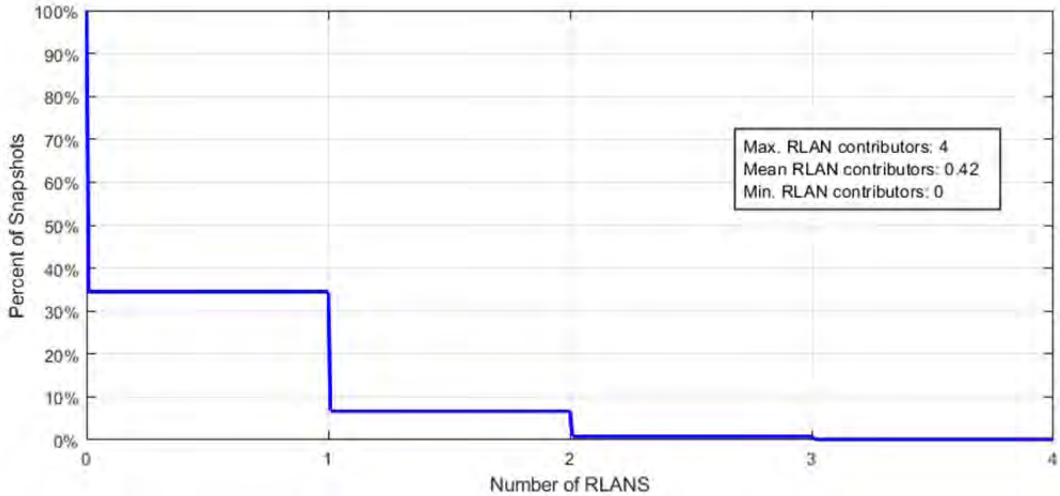

Figure 135. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

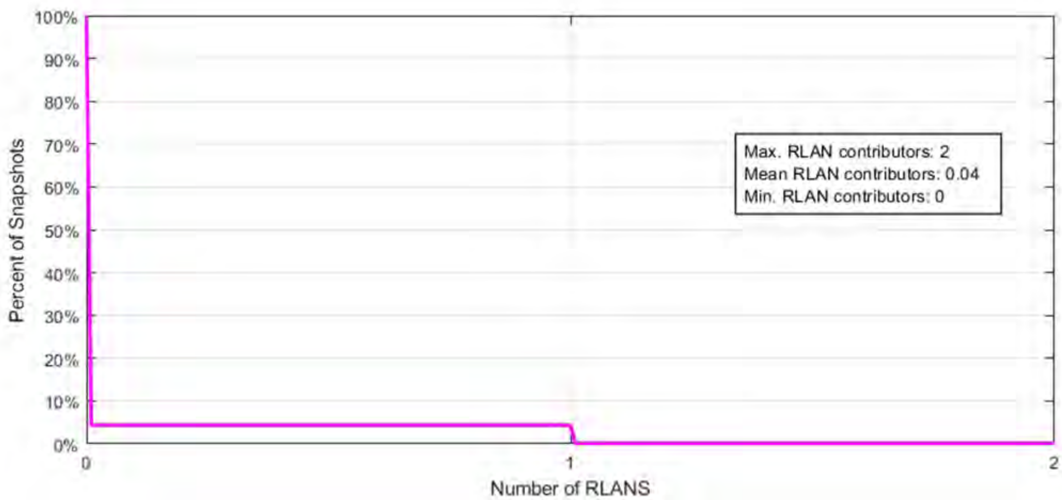

Figure 136. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

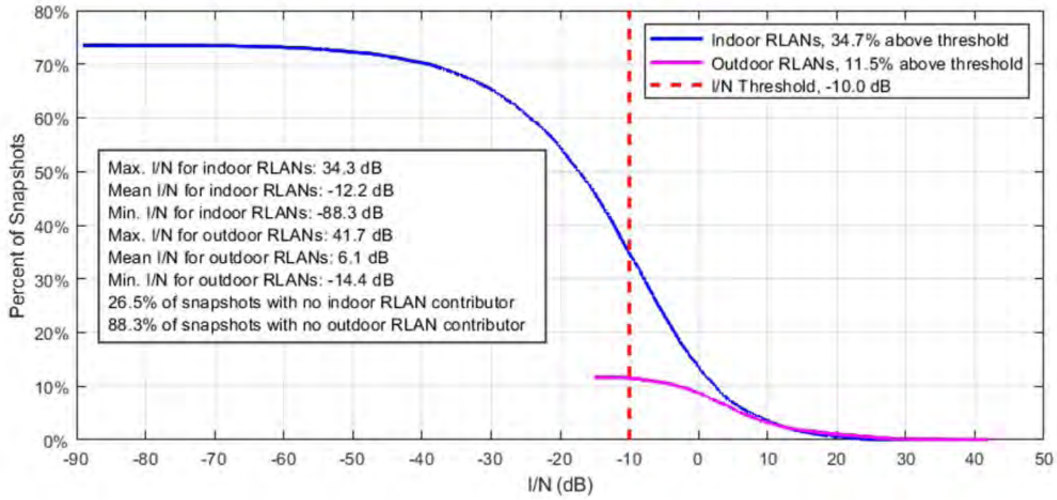

Figure 137. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

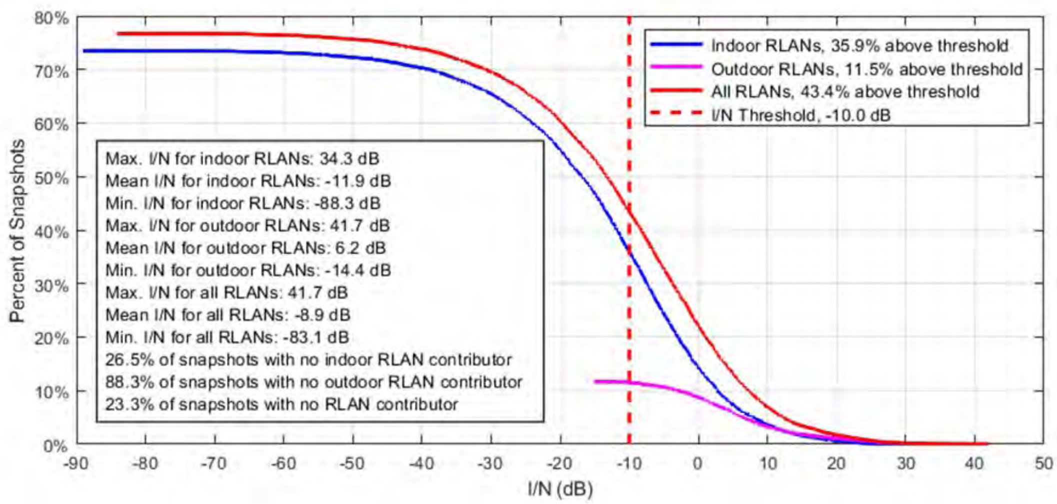

Figure 138. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

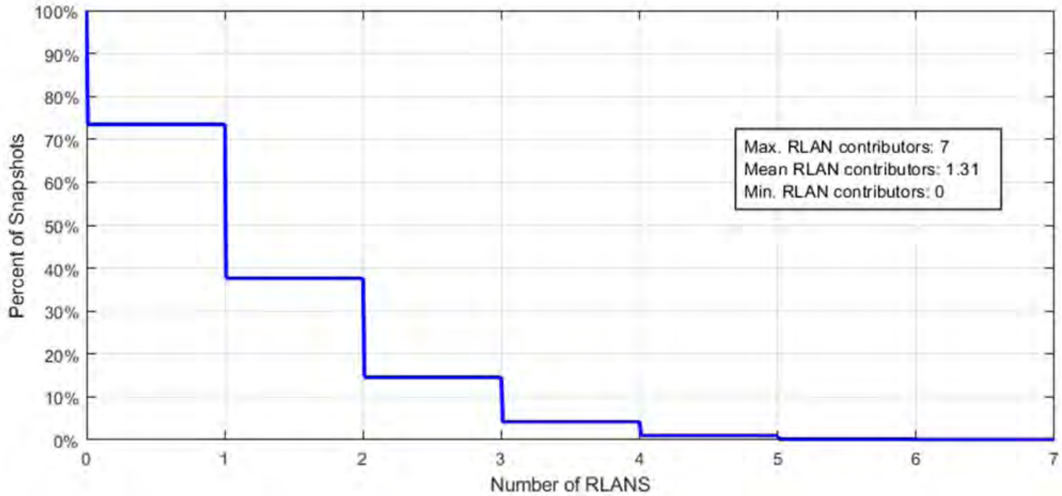

Figure 139. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

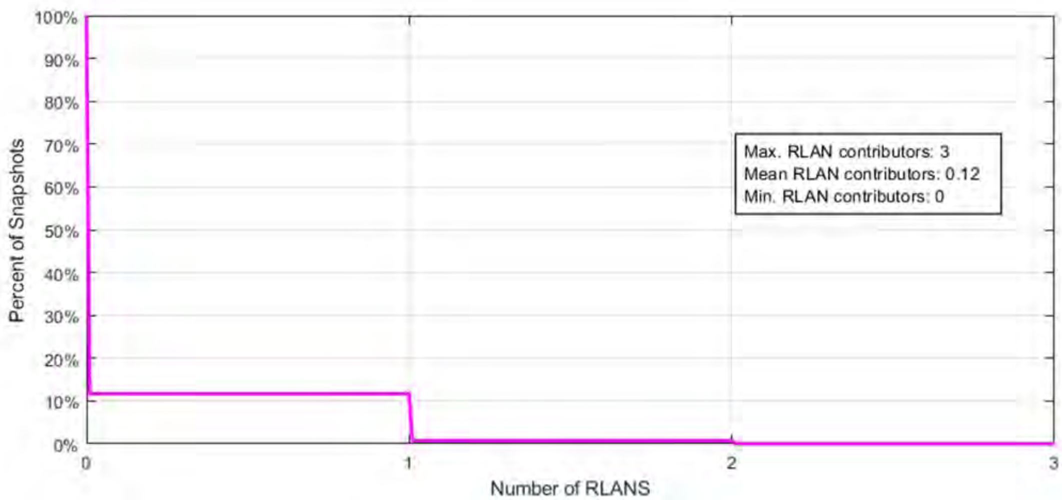

Figure 140. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

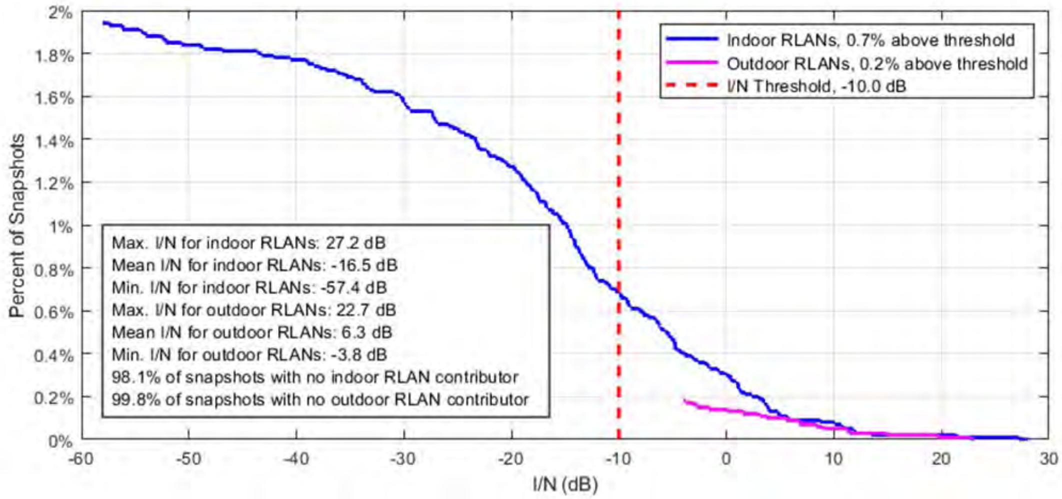

Figure 141. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

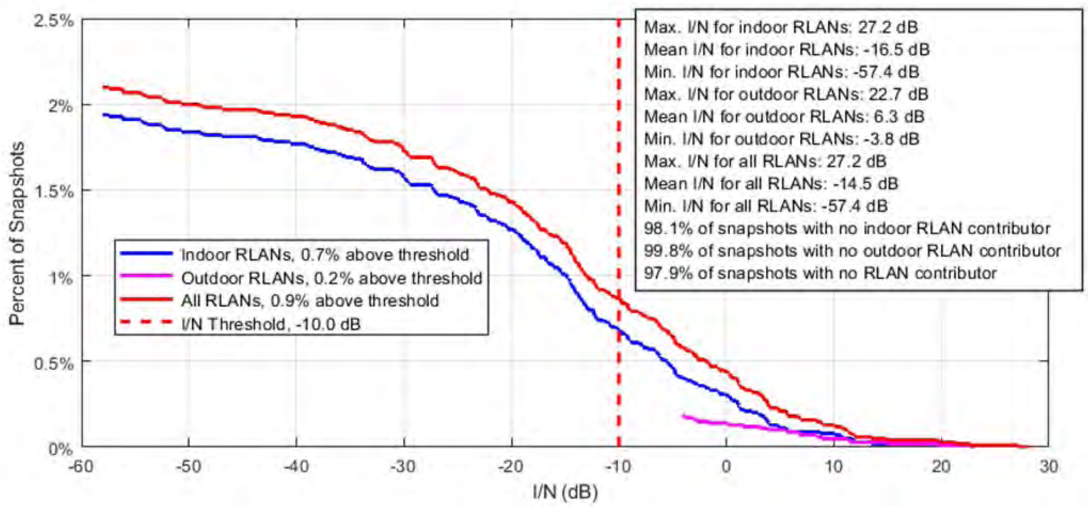

Figure 142. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

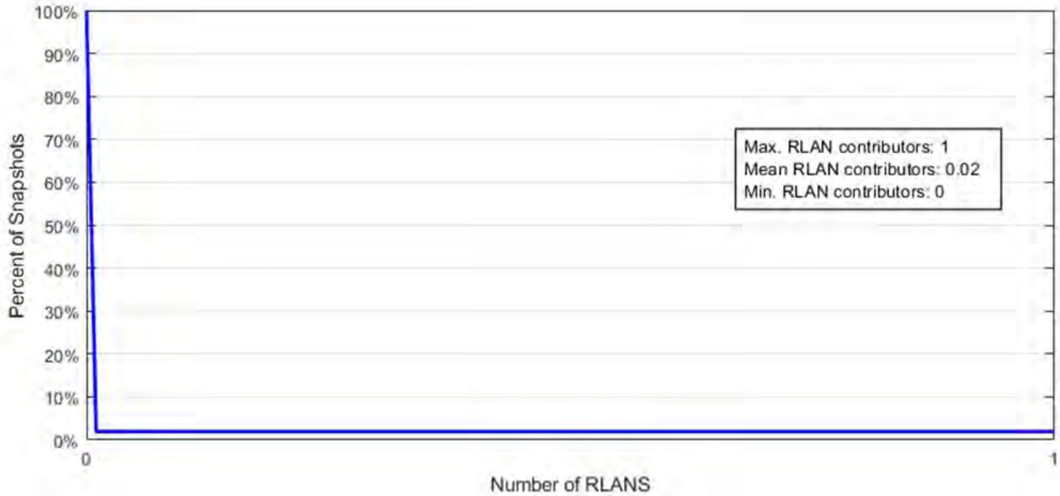

Figure 143. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

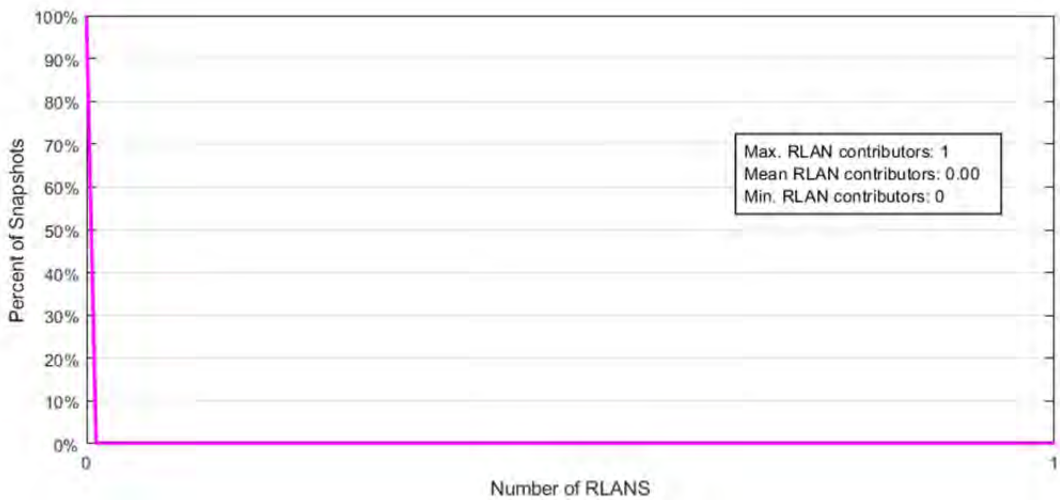

Figure 144. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 180 degrees (random angle)

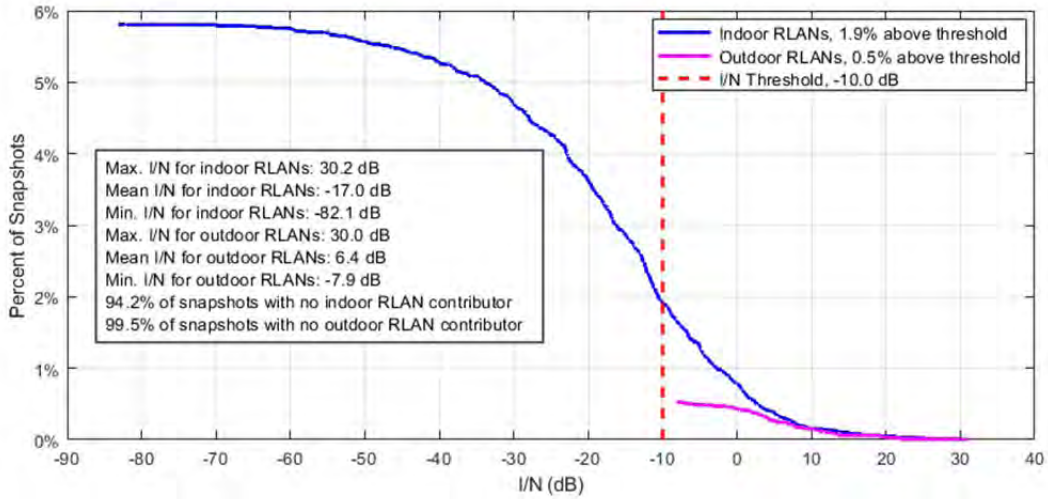

Figure 145. Max. single-entry RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

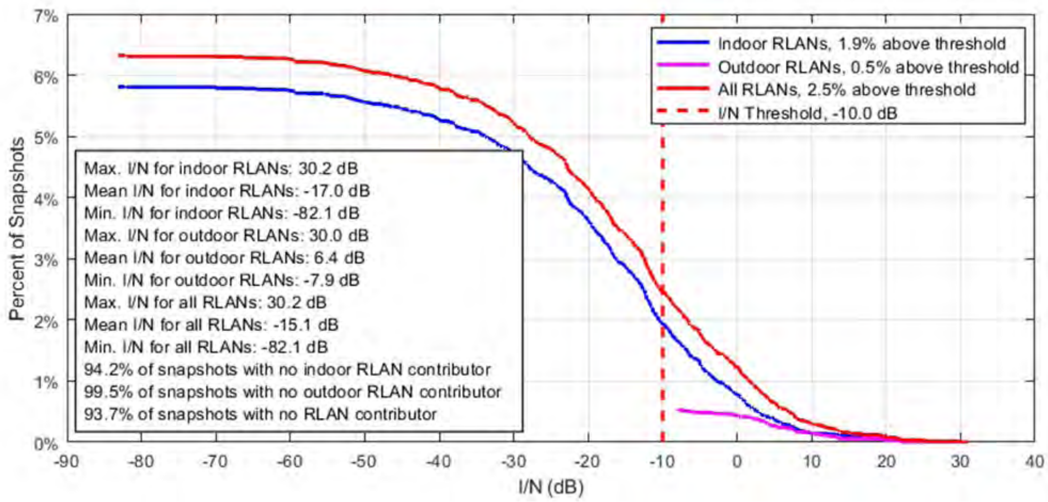

Figure 146. Aggregate RLAN I/N distribution, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

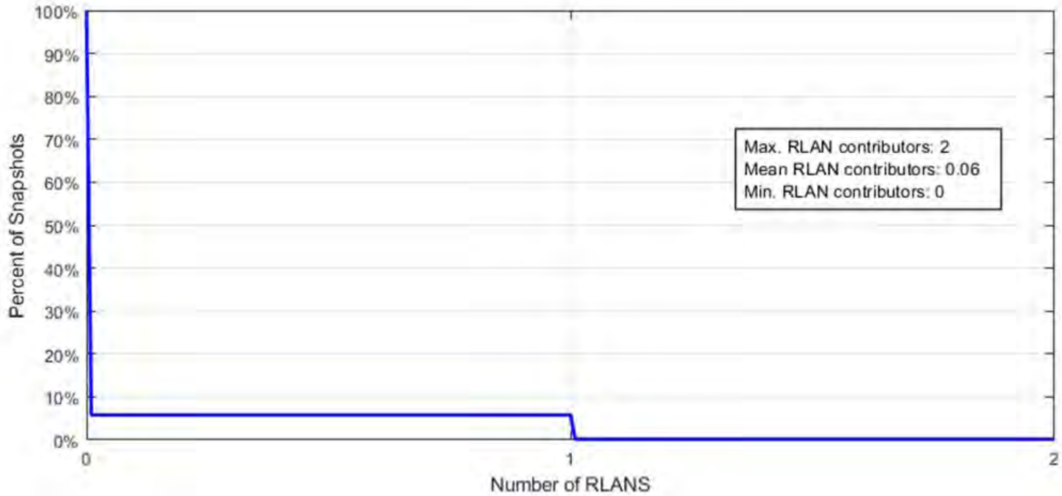

Figure 147. Number of indoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

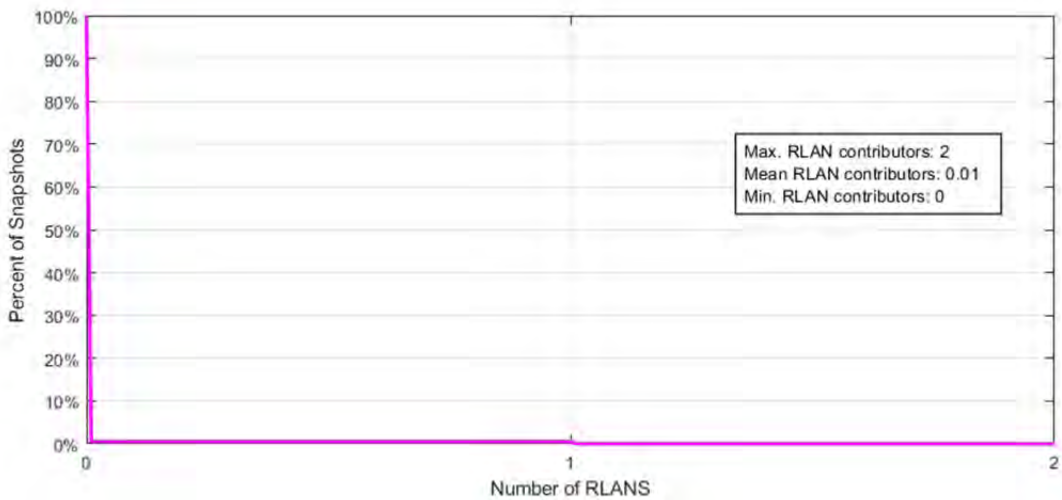

Figure 148. Number of outdoor RLAN contributors per snapshot, DC Mall ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 180 degrees (random angle)

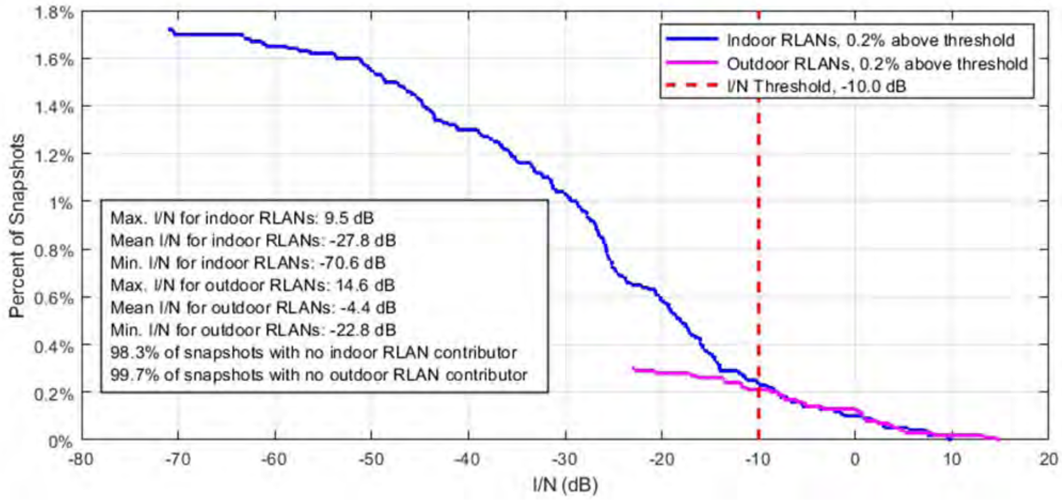

Figure 149. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

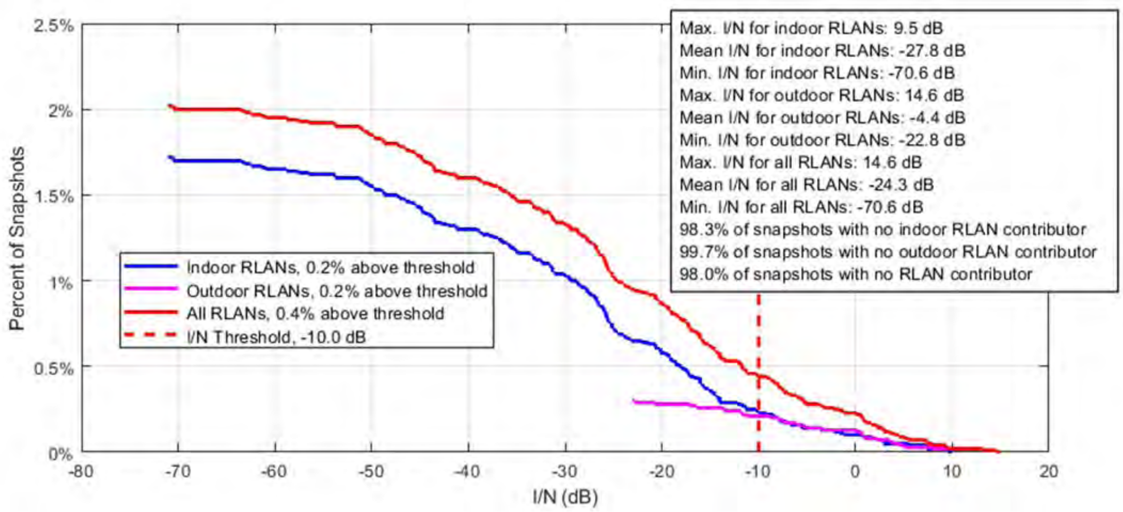

Figure 150. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

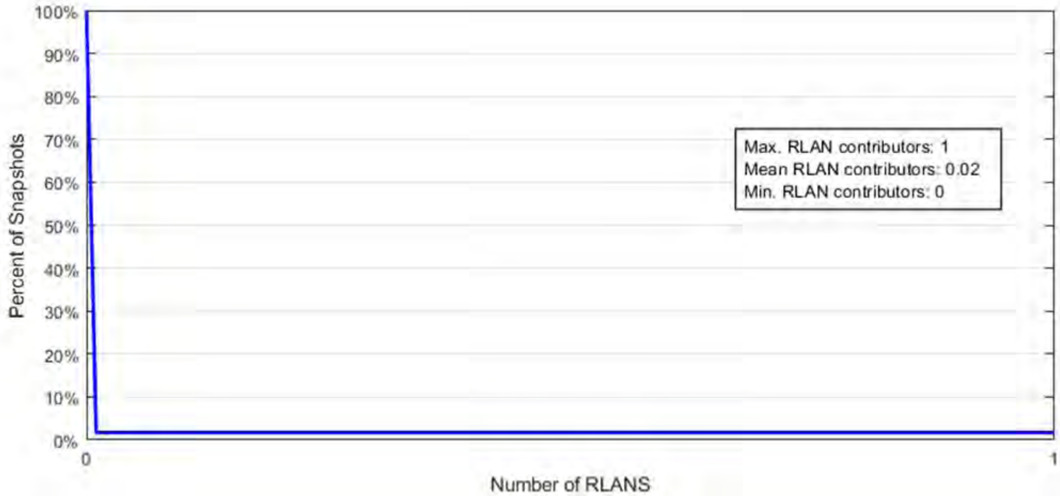

Figure 151. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

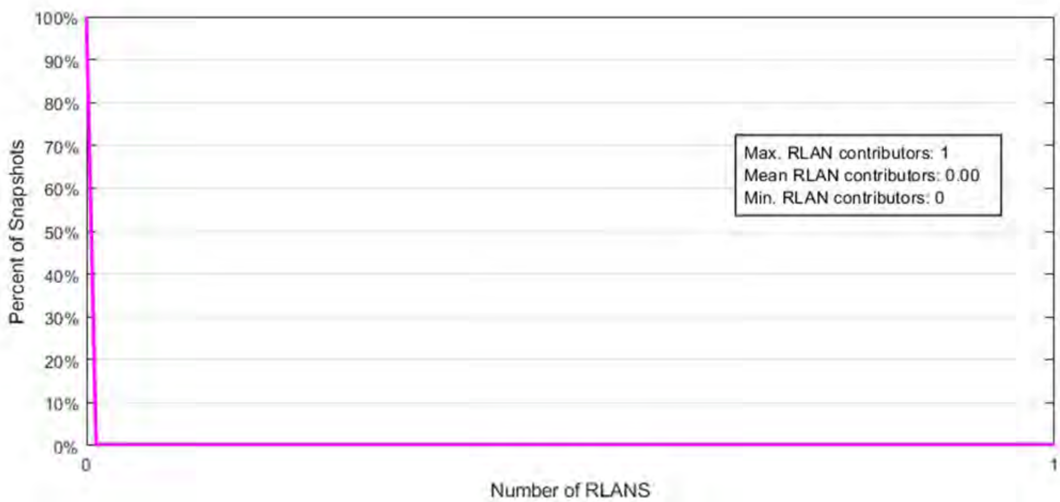

Figure 152. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

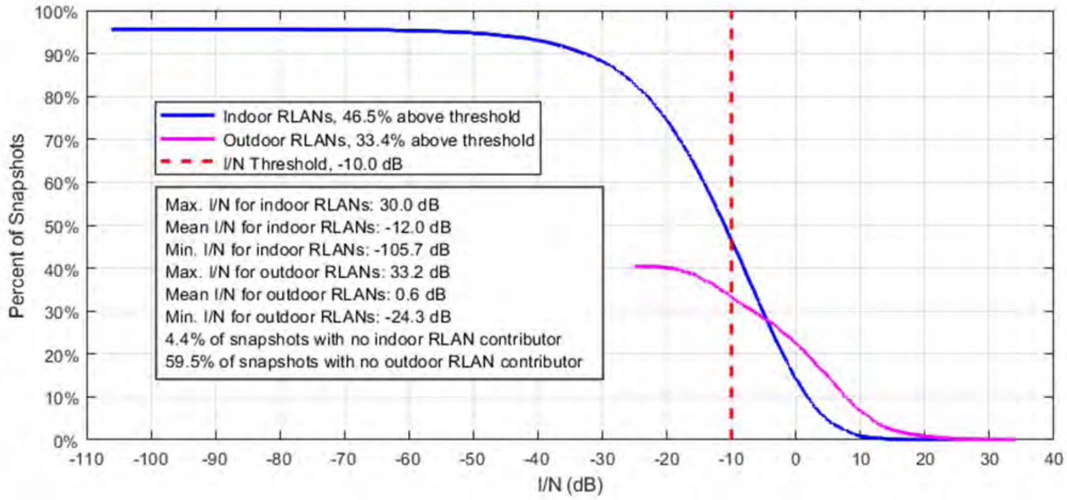

Figure 153. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

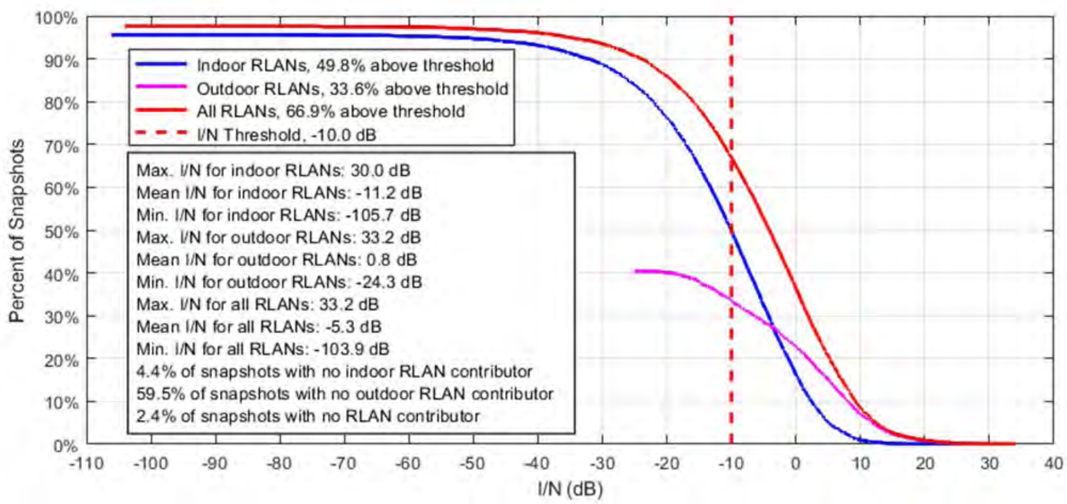

Figure 154. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

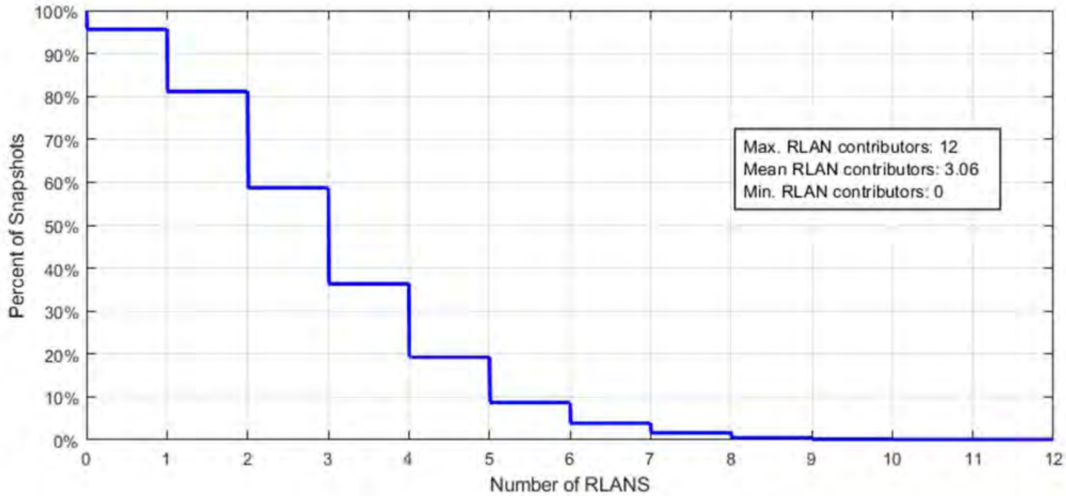

Figure 155. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

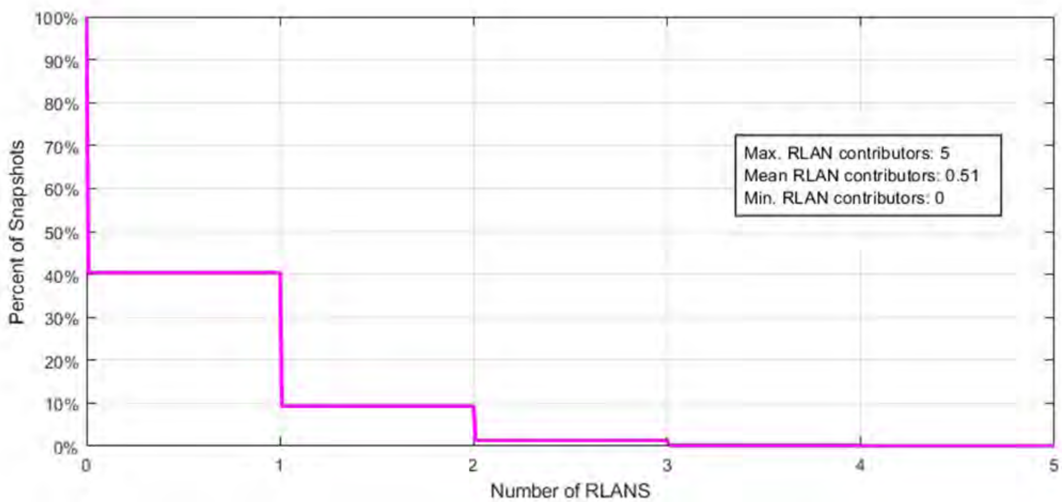

Figure 156. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

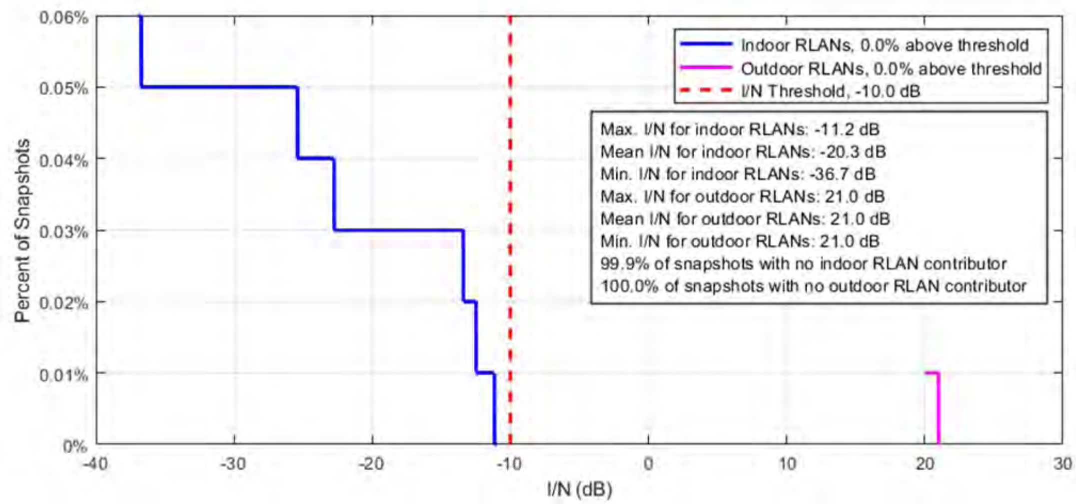

Figure 157. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

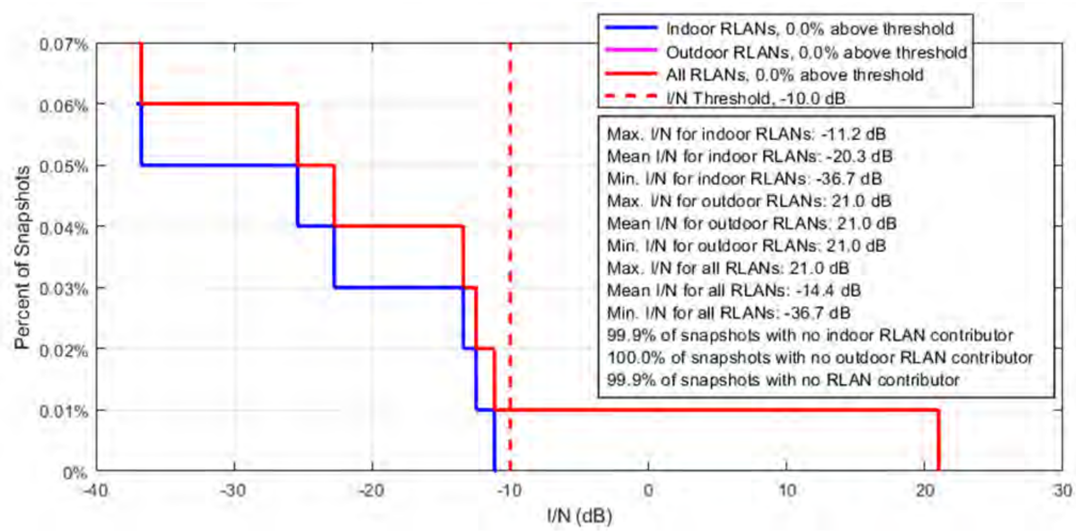

Figure 158. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

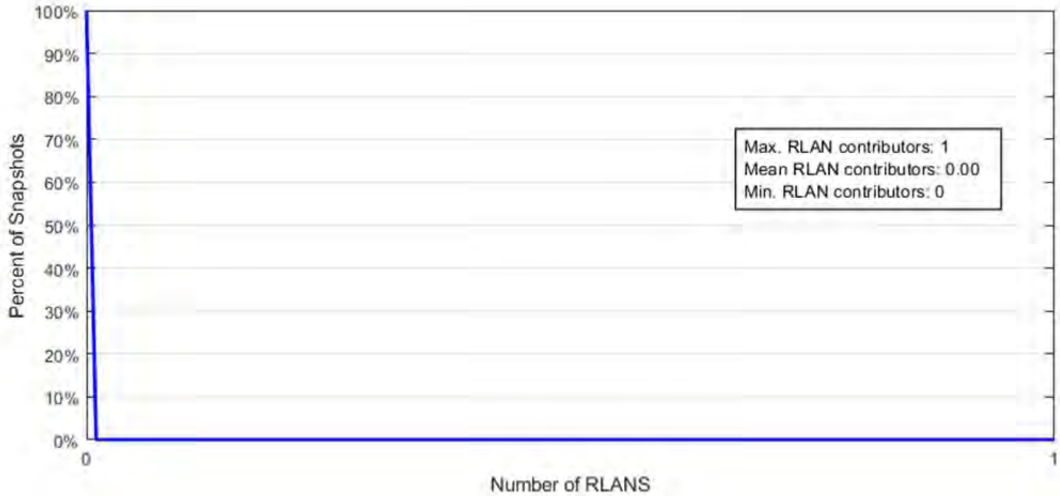

Figure 159. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

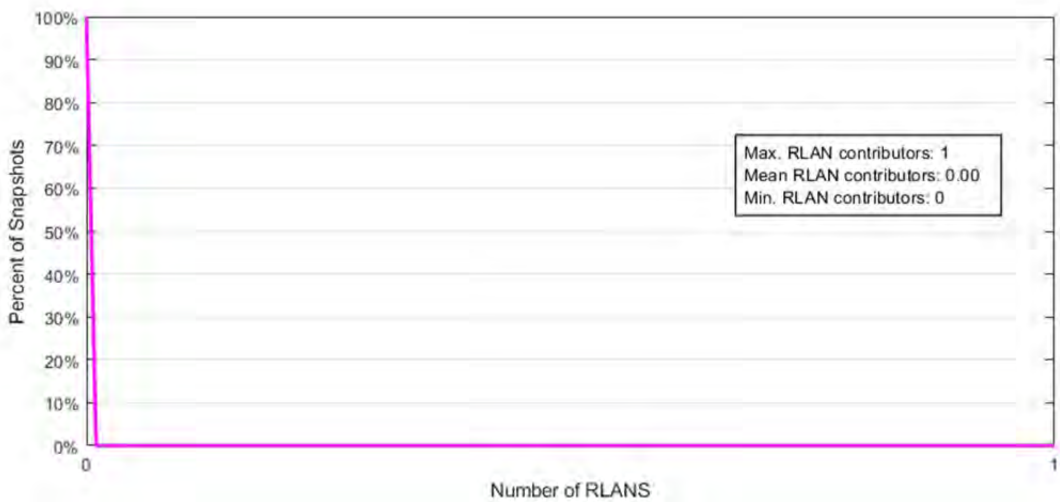

Figure 160. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 290 degrees (random angle)

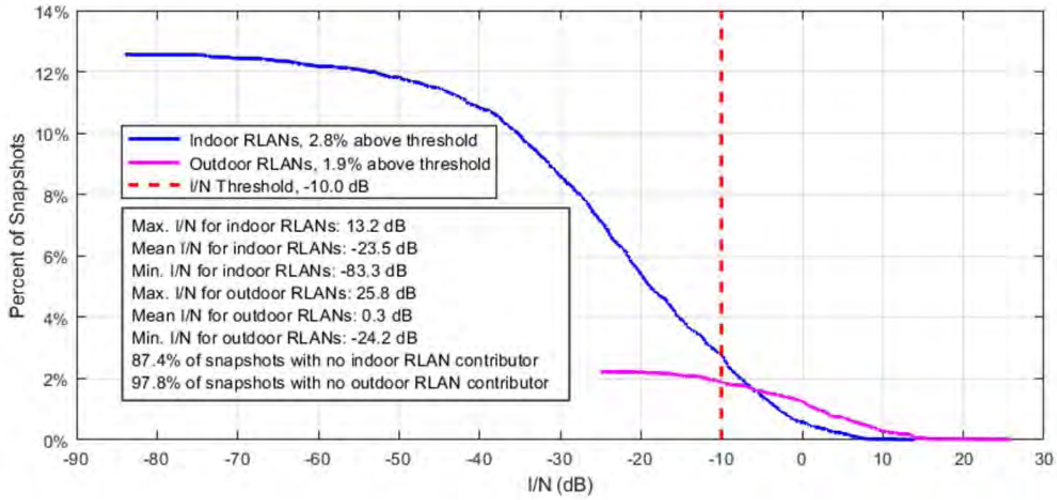

Figure 161. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

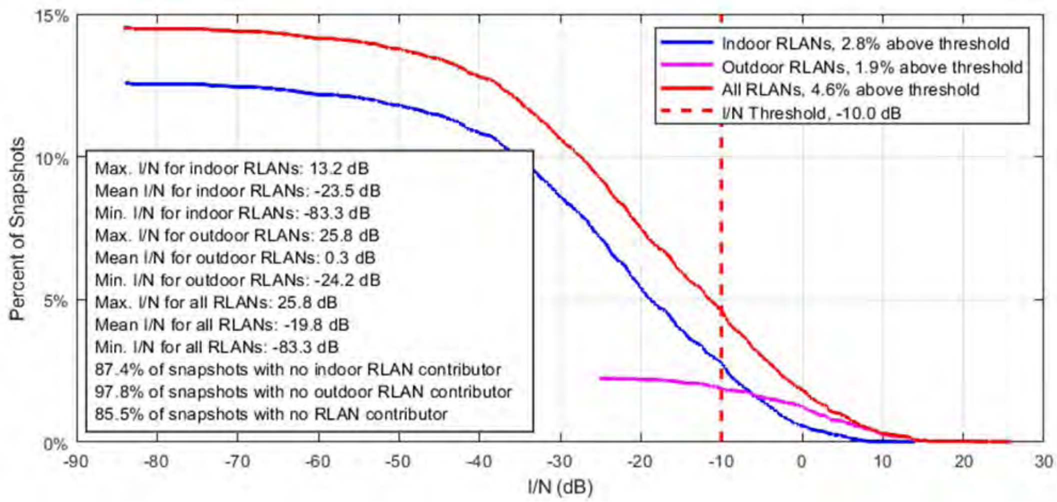

Figure 162. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

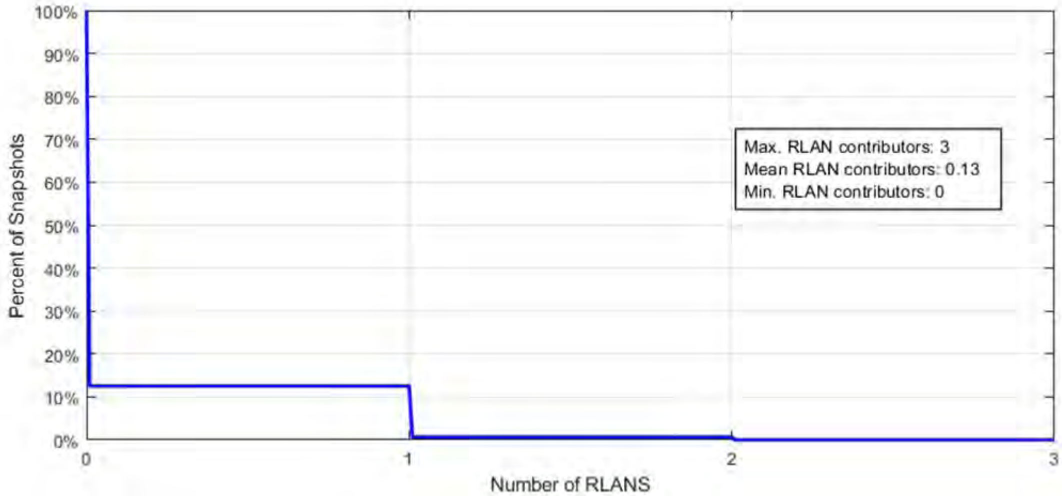

Figure 163. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

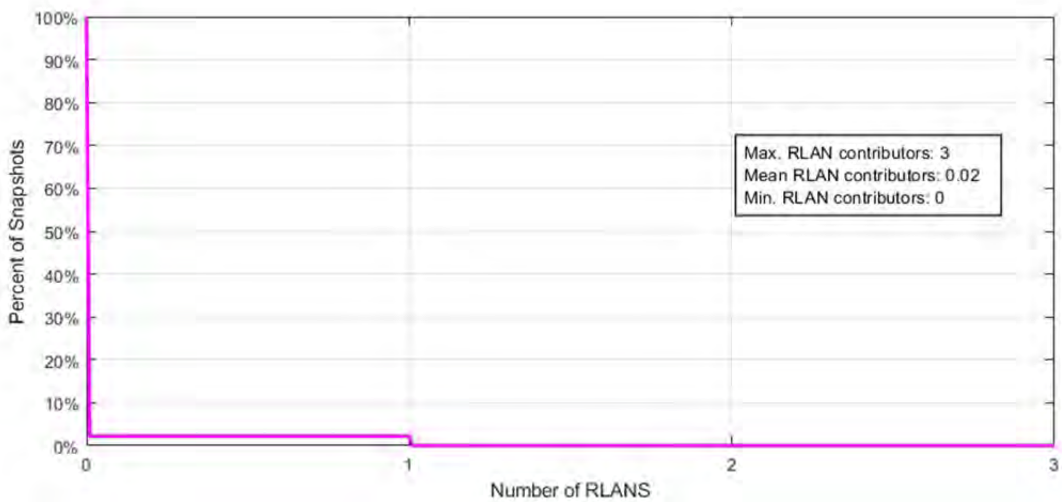

Figure 164. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 290 degrees (random angle)

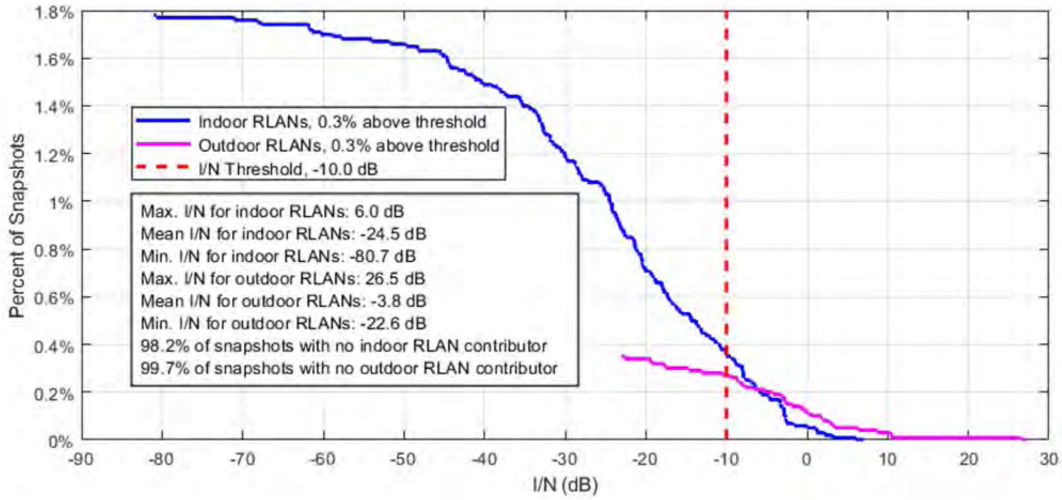

Figure 165. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

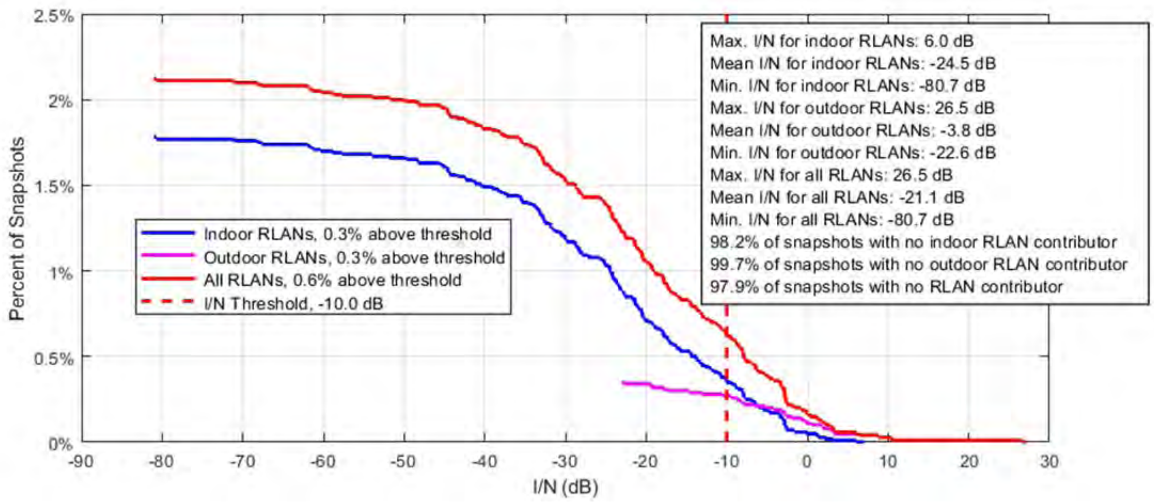

Figure 166. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

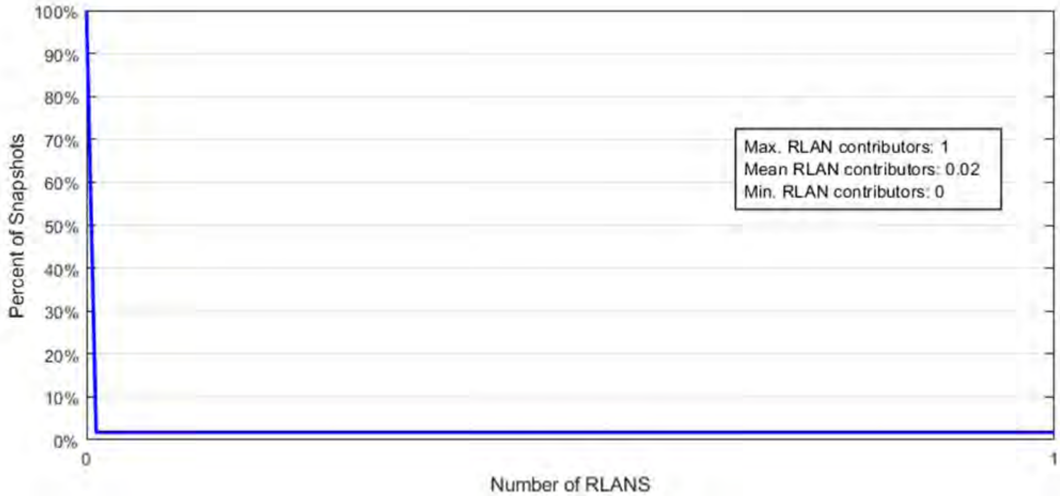

Figure 167. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

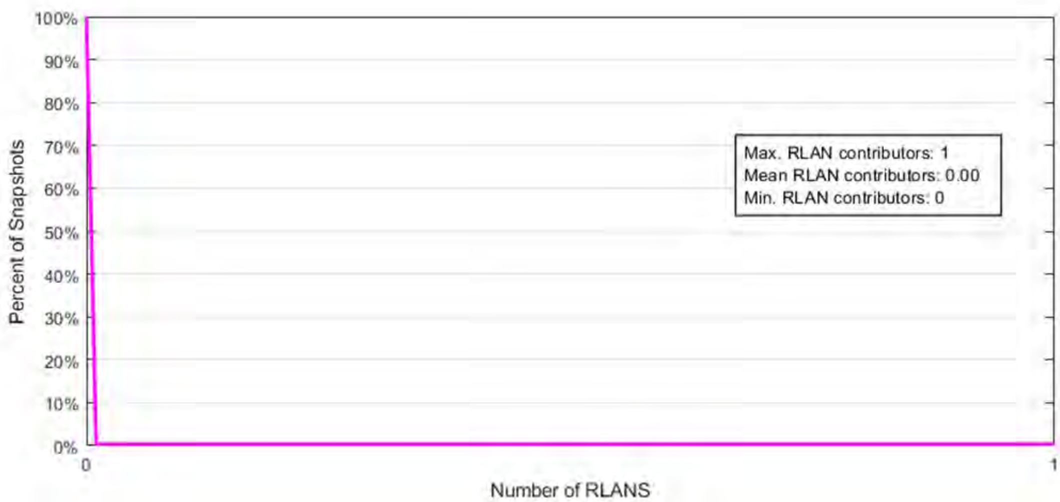

Figure 168. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

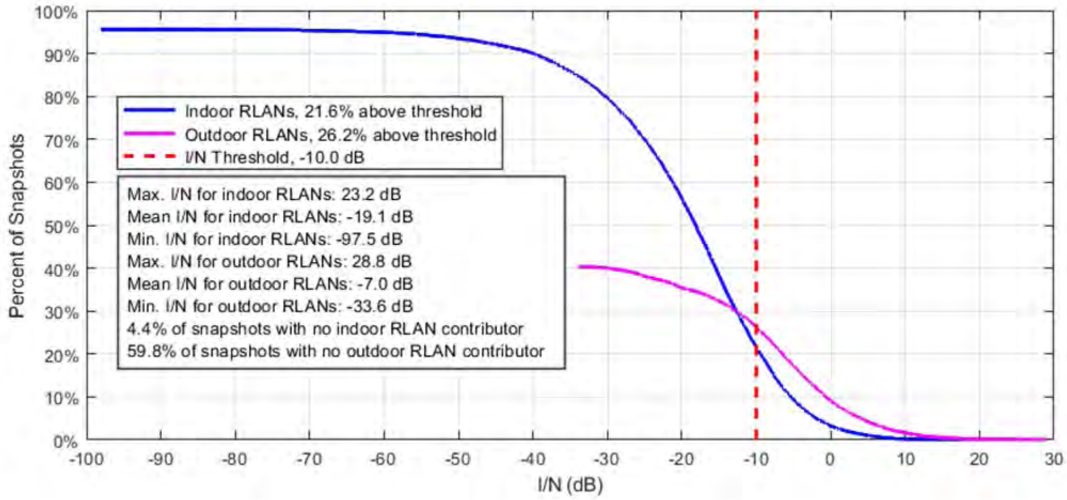

Figure 169. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

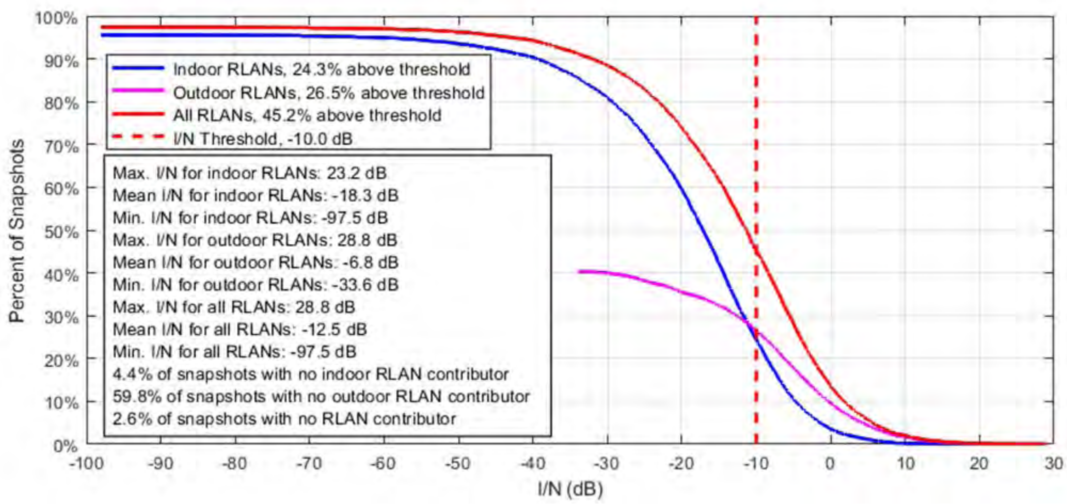

Figure 170. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

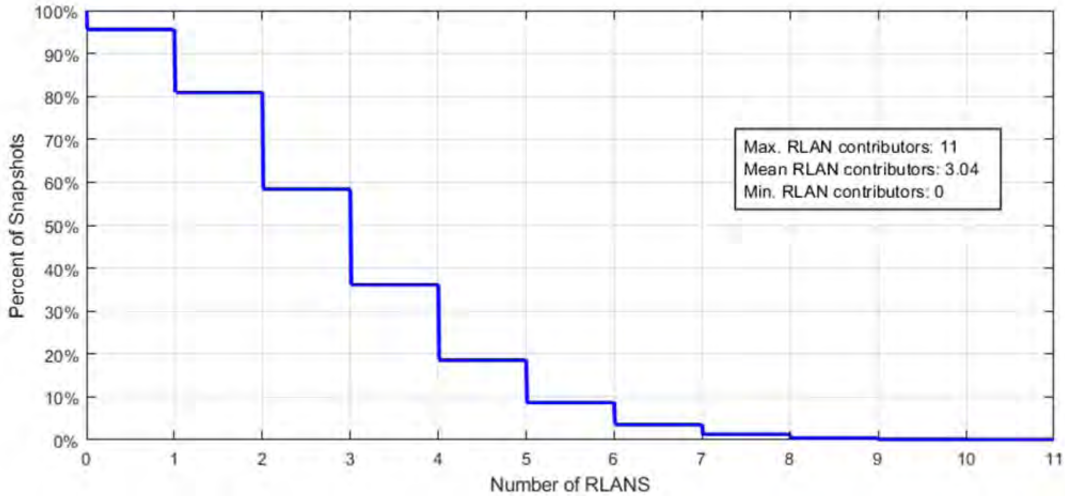

Figure 171. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

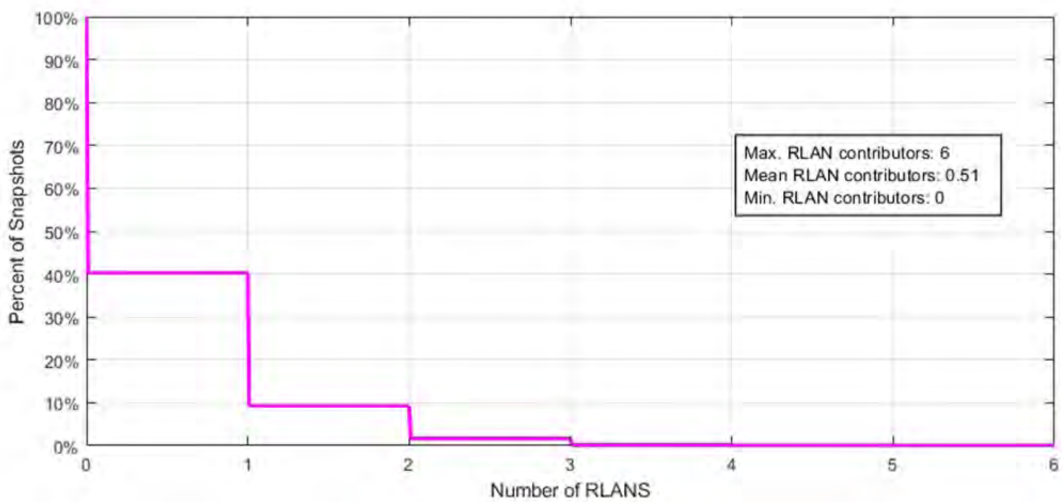

Figure 172. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 10%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

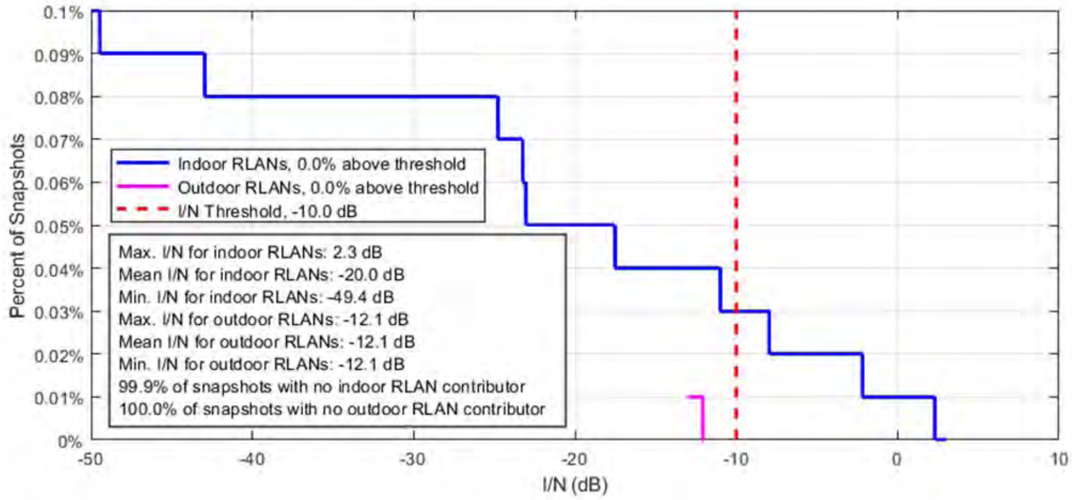

Figure 173. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

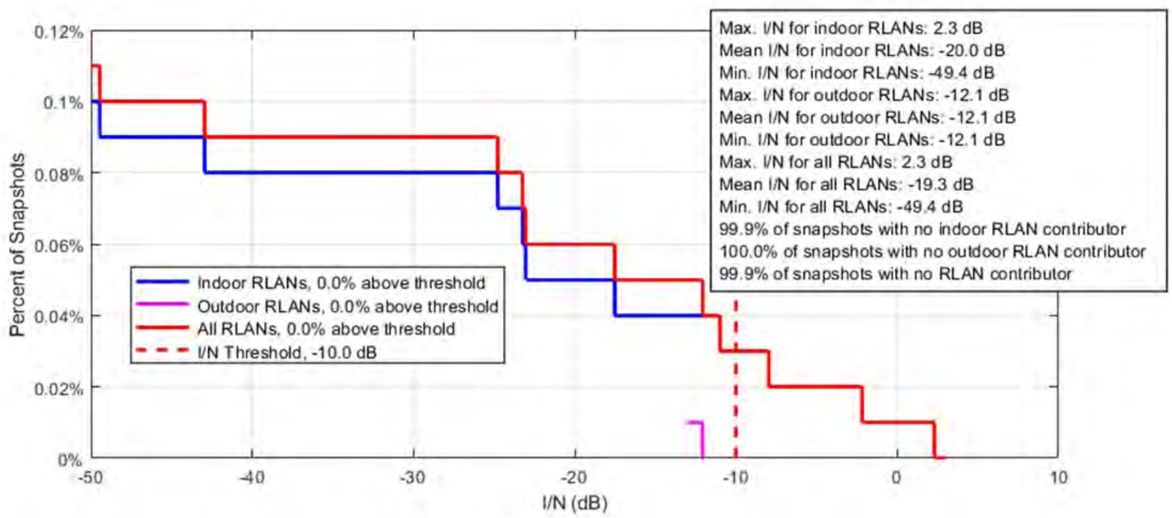

Figure 174. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

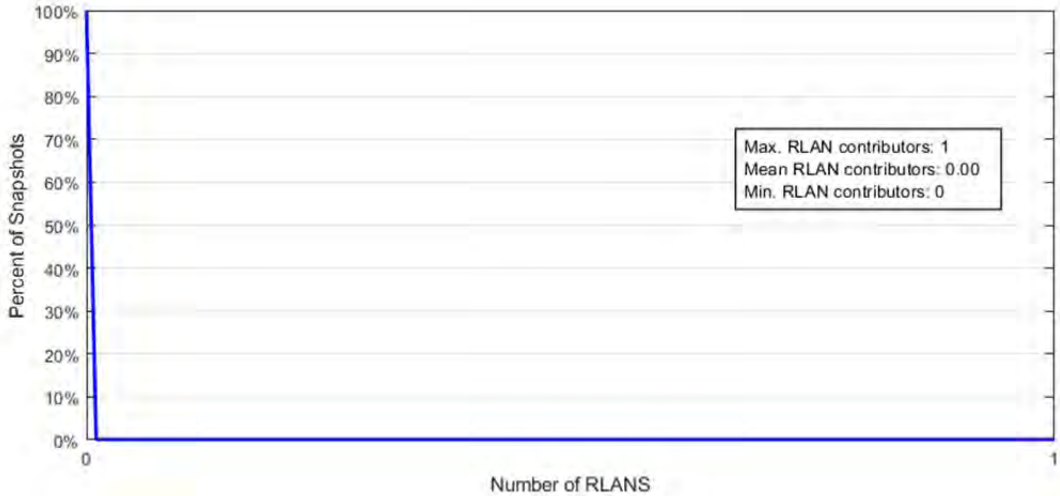

Figure 175. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

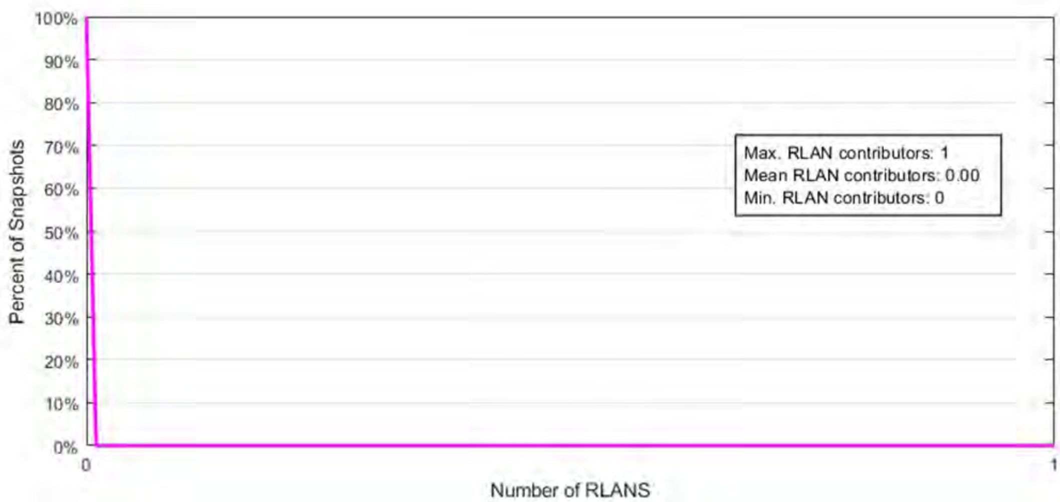

Figure 176. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 1.5 m height, antenna azimuth angle = 100 degrees (toward courthouse)

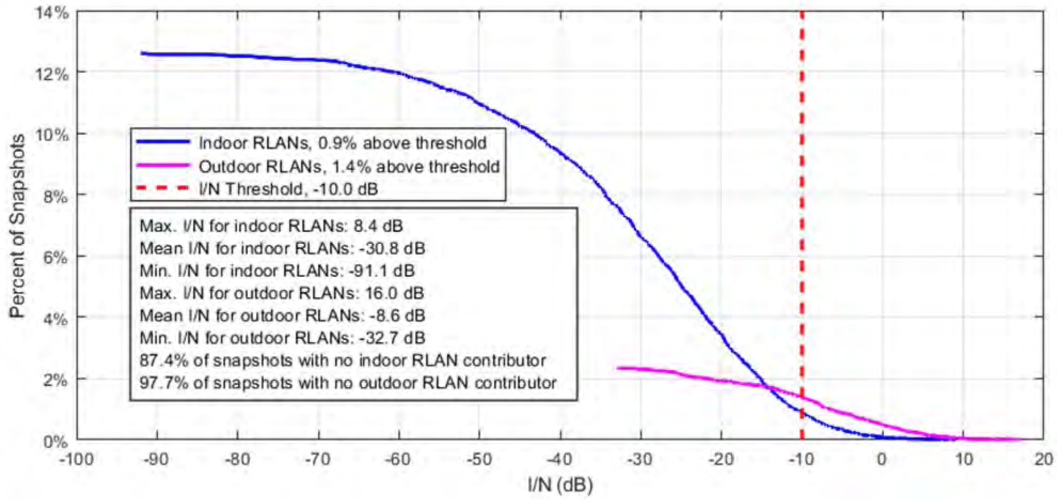

Figure 177. Max. single-entry RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

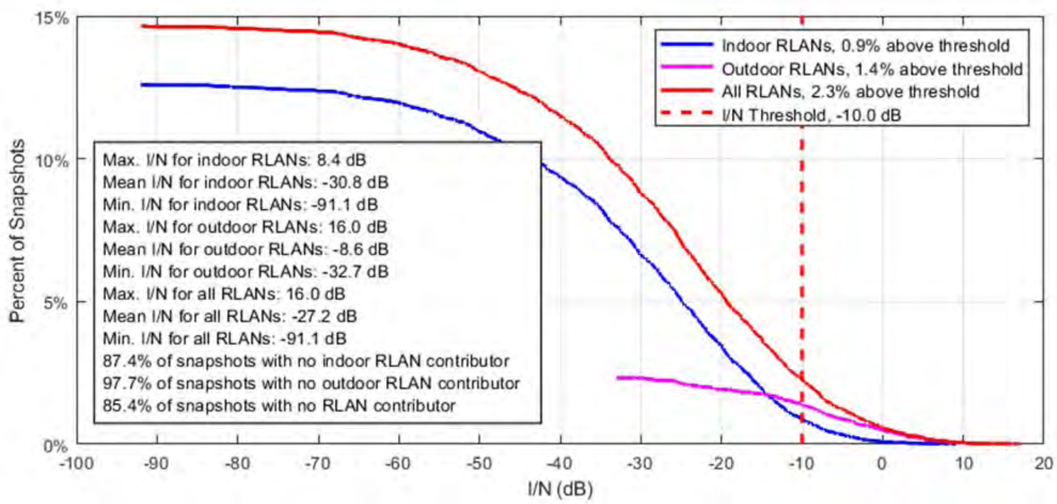

Figure 178. Aggregate RLAN I/N distribution, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

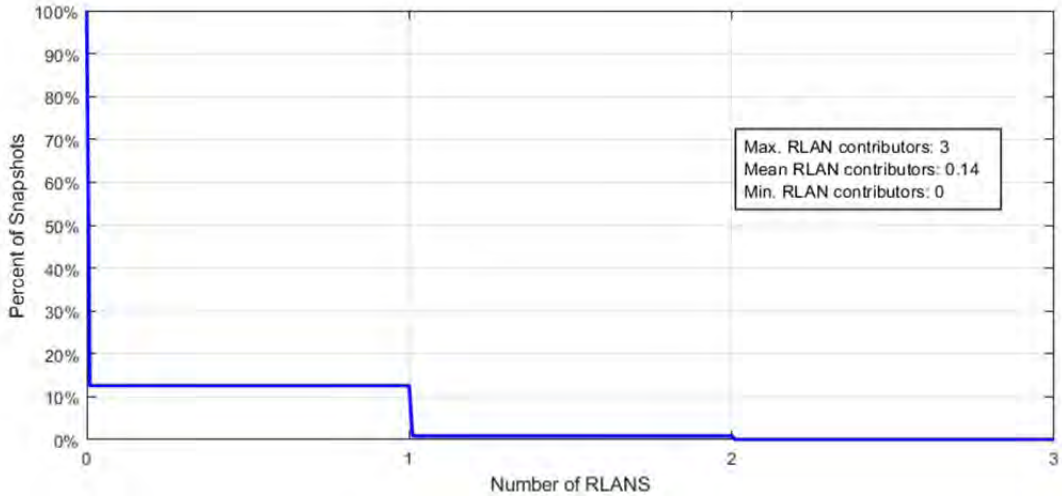

Figure 179. Number of indoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

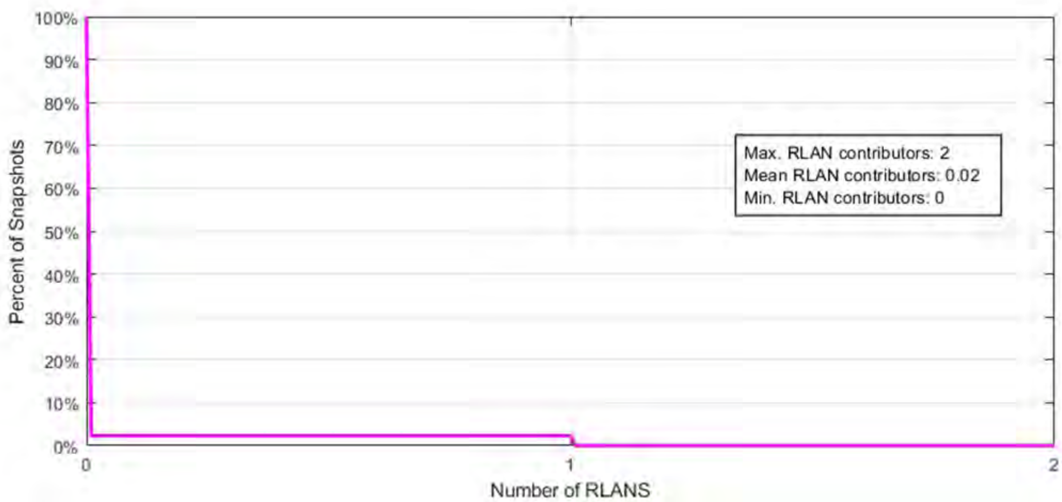

Figure 180. Number of outdoor RLAN contributors per snapshot, PG County Courthouse ENG truck, activity = 0.44%, sector antenna at 15 m height, antenna azimuth angle = 100 degrees (toward courthouse)

APPENDIX B – DETAILED ENG INTERIOR SCENARIO RESULTS (Cumulative Distributions and Summary Statistics)

This appendix provides detailed interior scenario results distributions for each of the cases shown in the summary table (Table 13). For each summary table entry, the following results distributions are provided:

- Maximum (per snapshot) single-entry RLAN I/N distribution for interior RLANs
- Aggregate RLAN I/N distribution for interior RLANs
- Number of interior RLAN contributors per snapshot

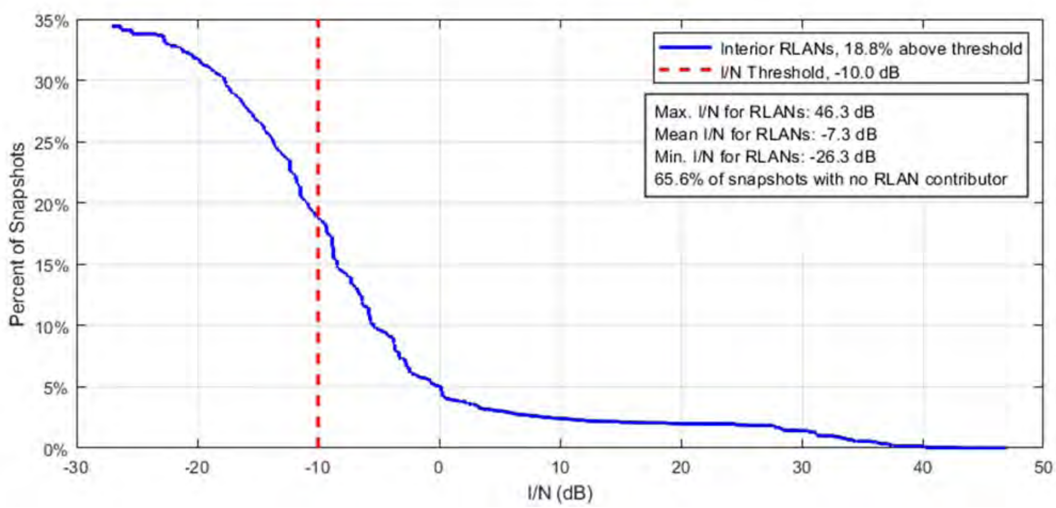

Figure 181. Max. single-entry RLAN I/N distribution, 4 interior RLANs, activity = 10%

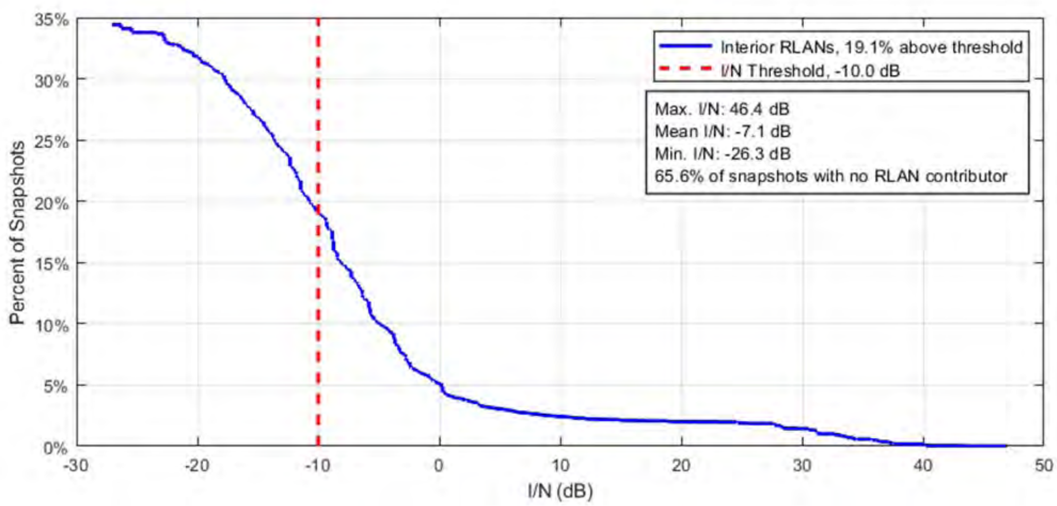

Figure 182. Aggregate RLAN I/N distribution, 4 interior RLANs, activity = 10%

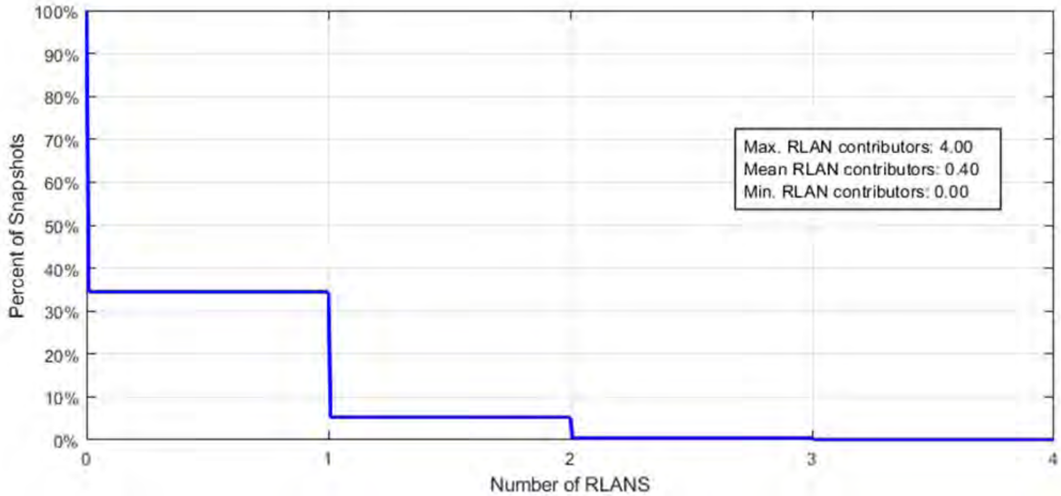

Figure 183. Number of RLAN contributors per snapshot, 4 interior RLANs, activity = 10%

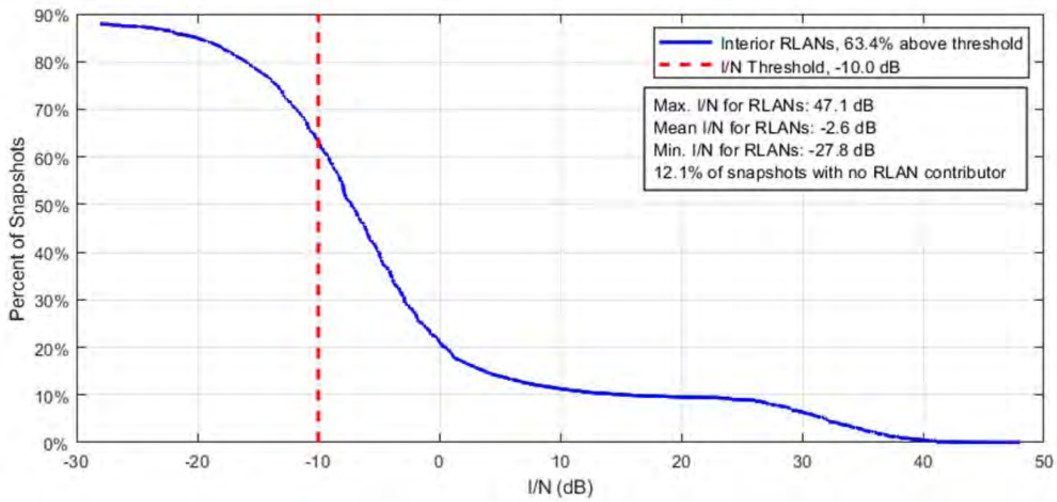

Figure 184. Max. single-entry RLAN I/N distribution, 20 interior RLANs, activity = 10%

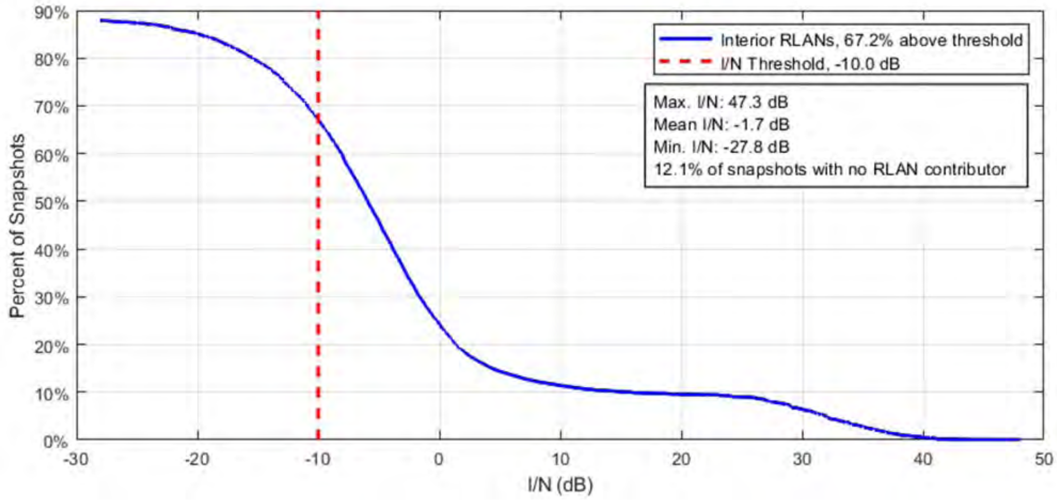

Figure 185. Aggregate RLAN I/N distribution, 20 interior RLANs, activity = 10%

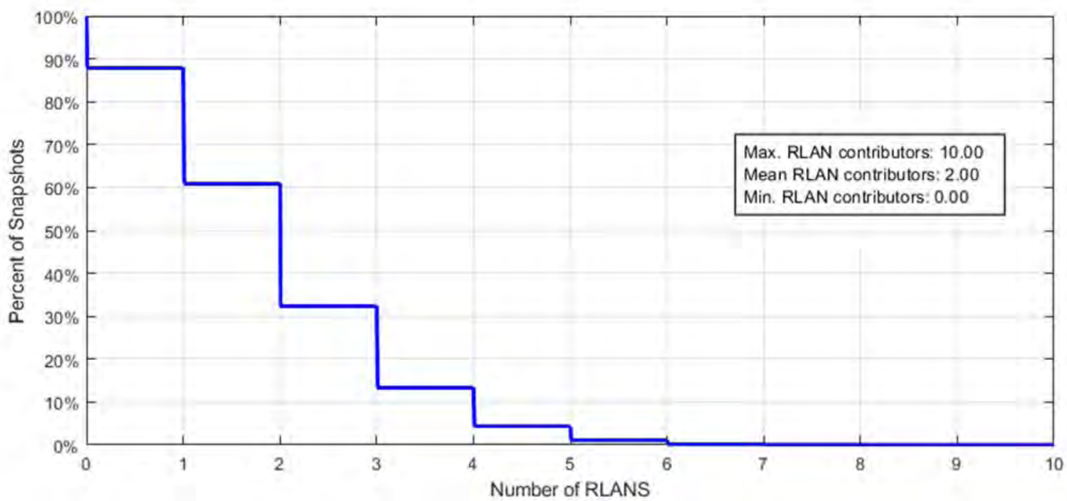

Figure 186. Number of RLAN contributors per snapshot, 20 interior RLANs, activity = 10%

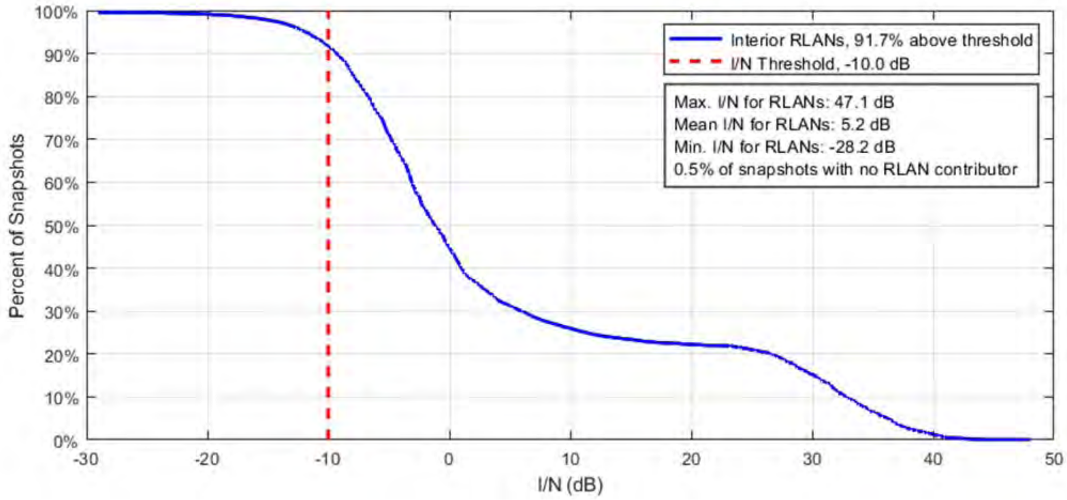

Figure 187. Max. single-entry RLAN I/N distribution, 50 interior RLANs, activity = 10%

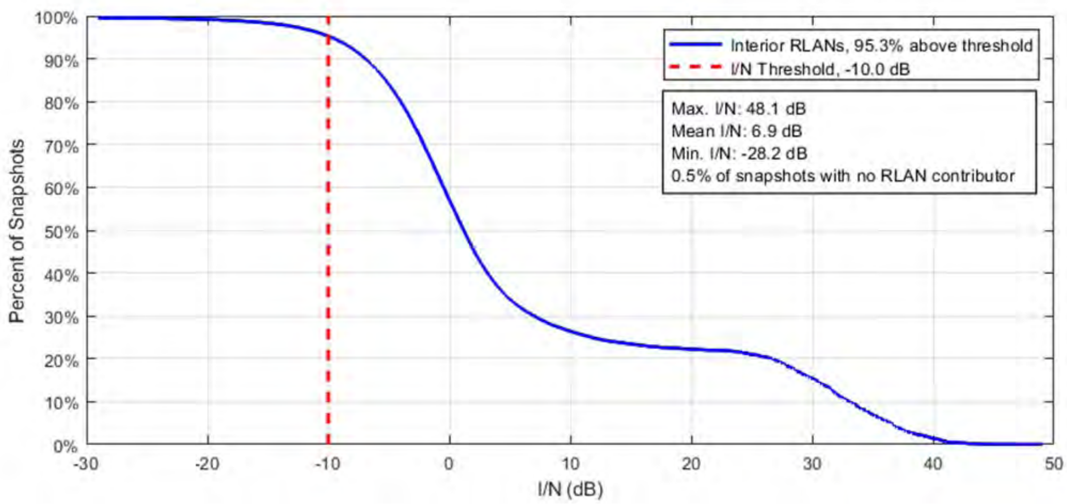

Figure 188. Aggregate RLAN I/N distribution, 50 interior RLANs, activity = 10%

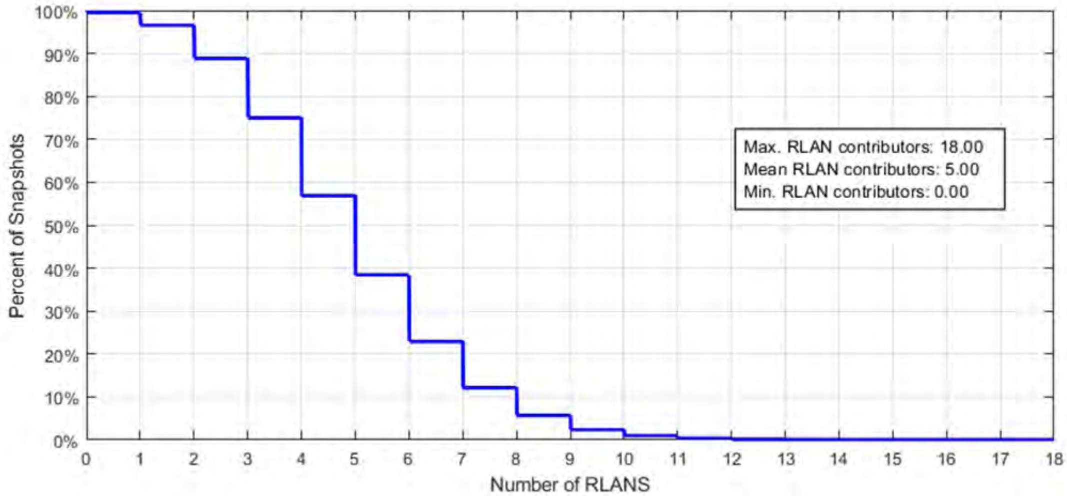

Figure 189. Number of RLAN contributors per snapshot, 50 interior RLANs, activity = 10%

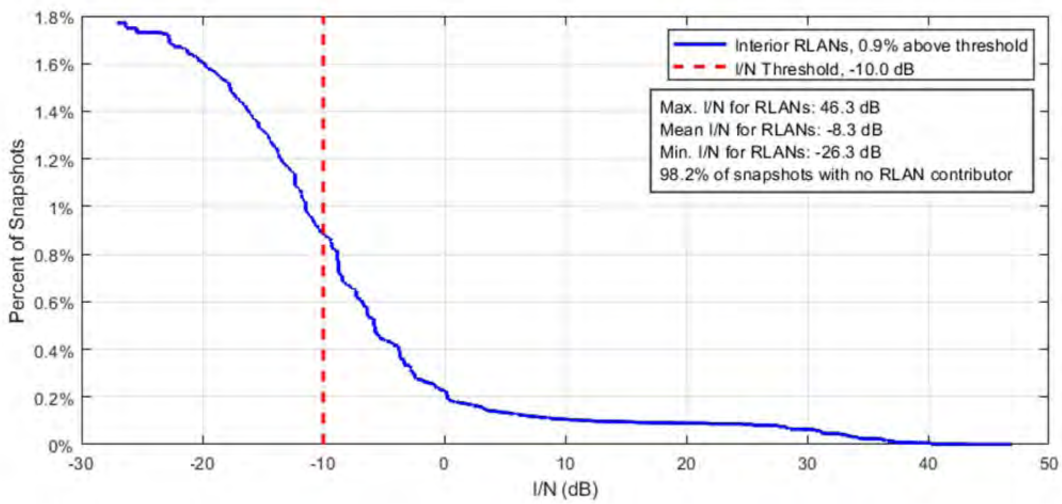

Figure 190. Max. single-entry RLAN I/N distribution, 4 interior RLANs, activity = 0.44%

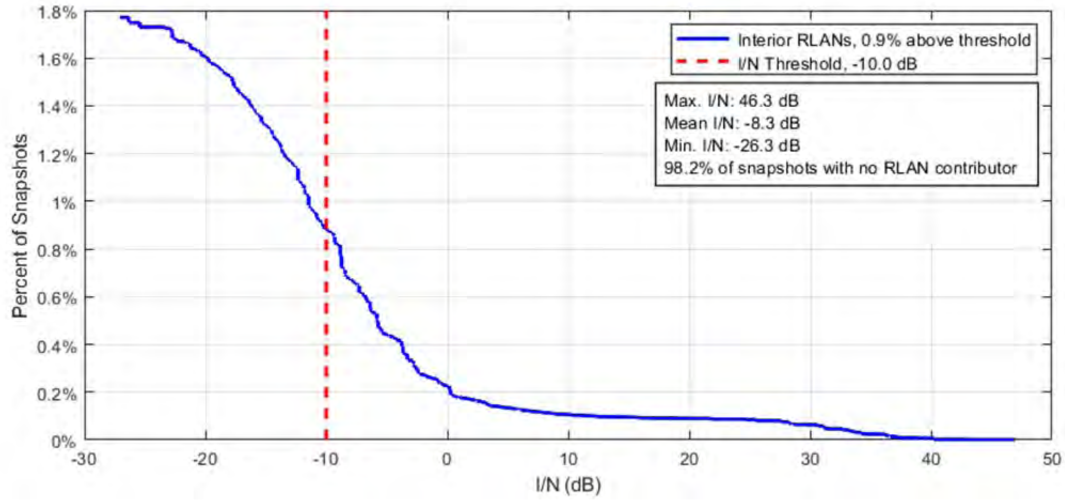

Figure 191. Aggregate RLAN I/N distribution, 4 interior RLANs, activity = 0.44%

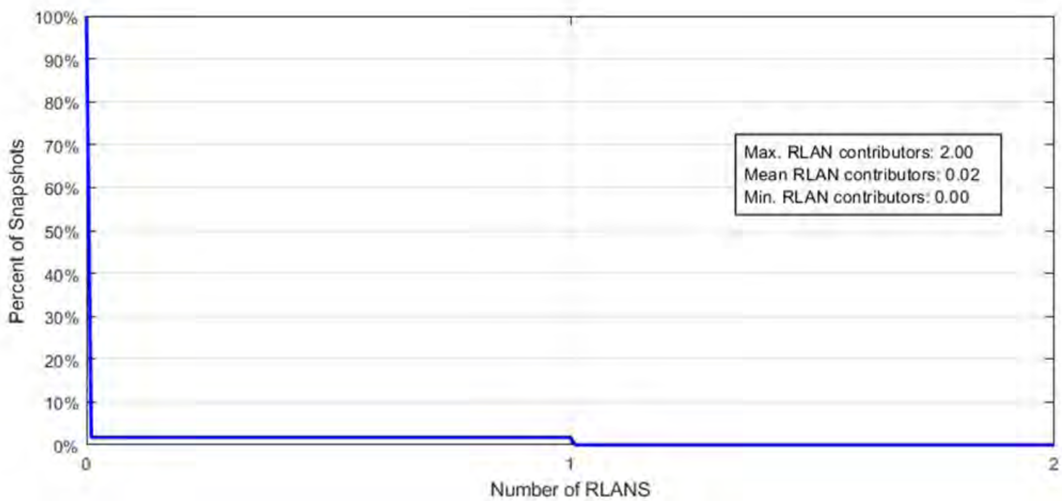

Figure 192. Number of RLAN contributors per snapshot, 4 interior RLANs, activity = 0.44%

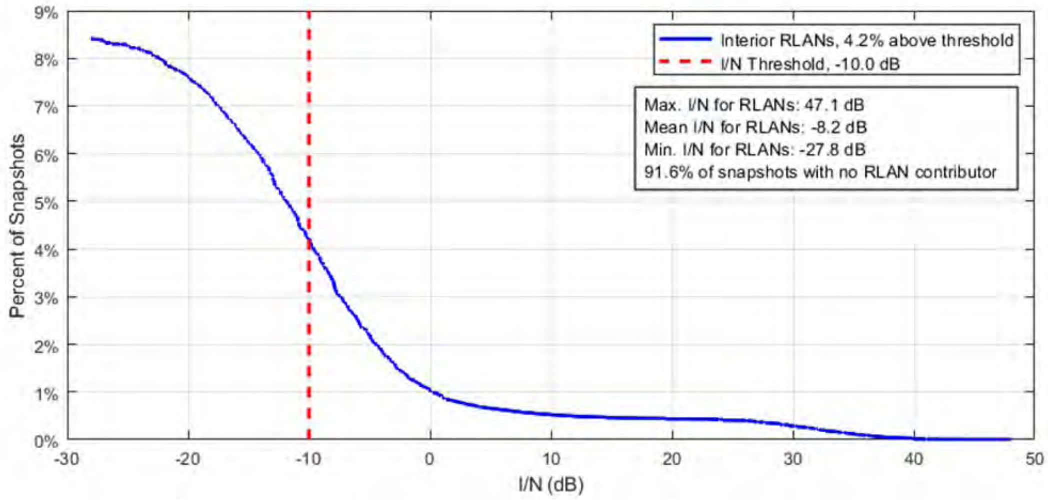

Figure 193. Max. single-entry RLAN I/N distribution, 20 interior RLANs, activity = 0.44%

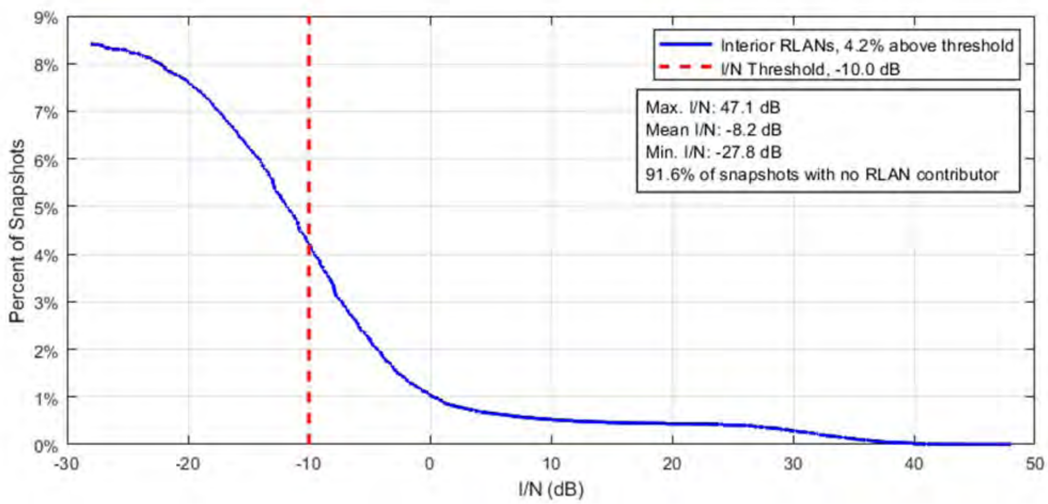

Figure 194. Aggregate RLAN I/N distribution, 20 interior RLANs, activity = 0.44%

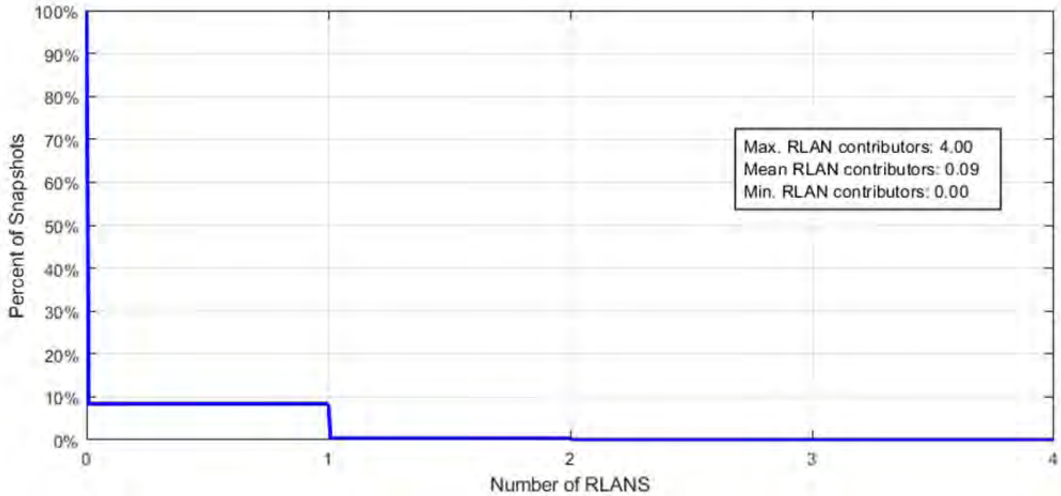

Figure 195. Number of RLAN contributors per snapshot, 20 interior RLANs, activity = 0.44%

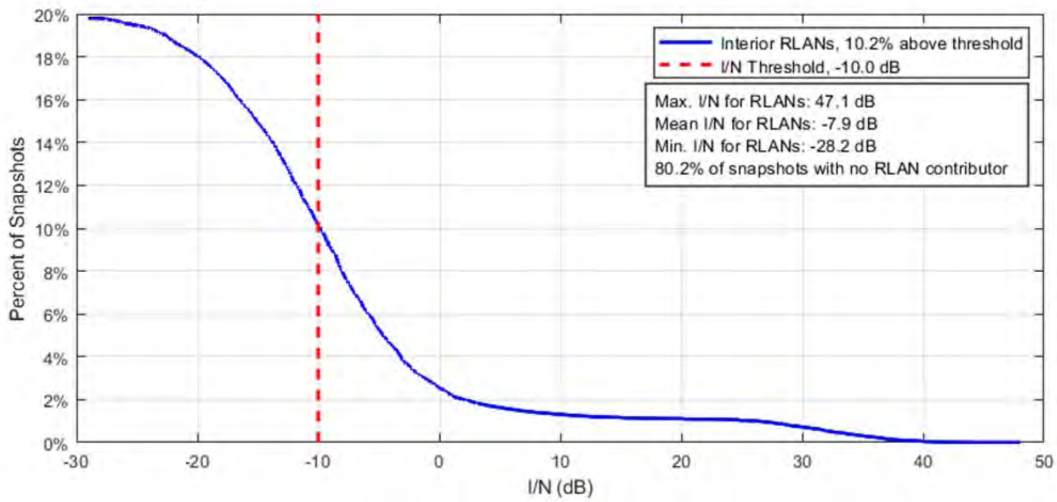

Figure 196. Max. single-entry RLAN I/N distribution, 50 interior RLANs, activity = 0.44%

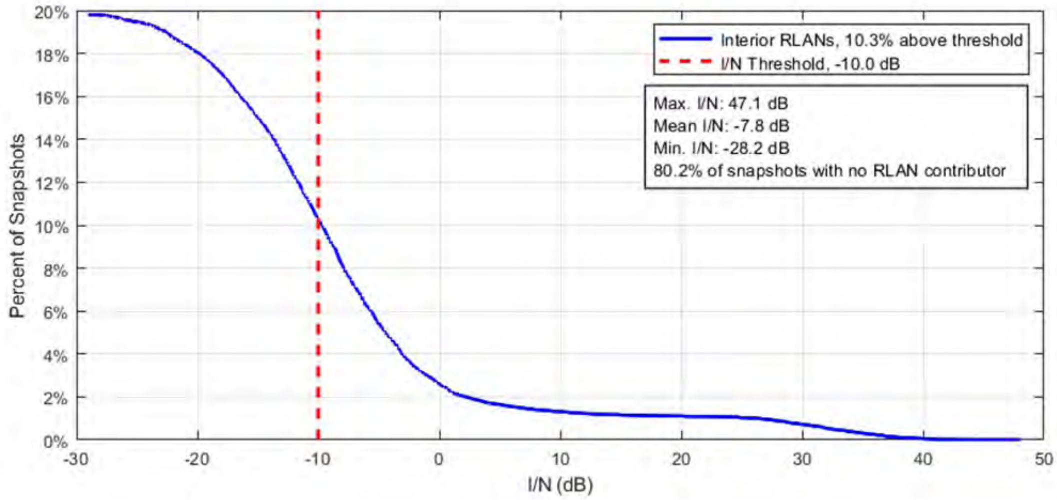

Figure 197. Aggregate RLAN I/N distribution, 50 interior RLANs, activity = 0.44%

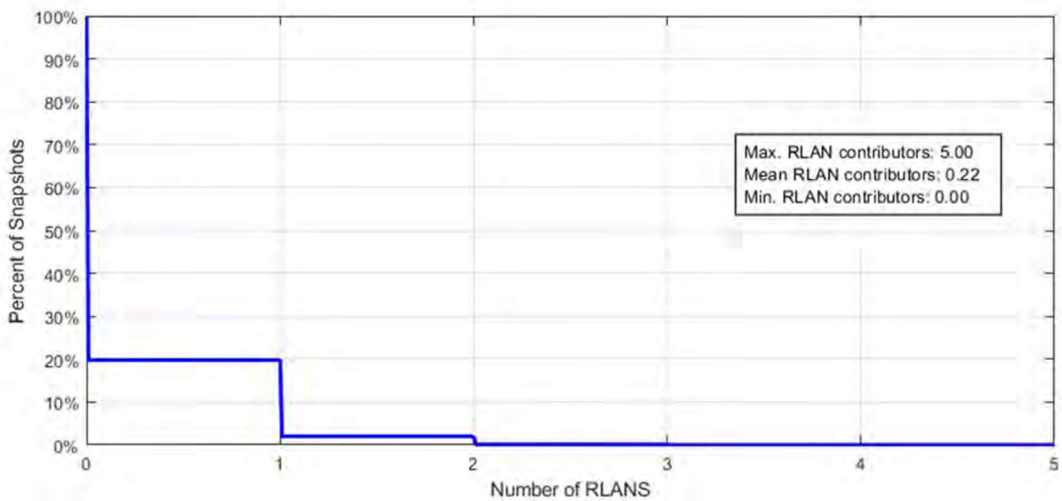

Figure 198. Number of RLAN contributors per snapshot, 50 interior RLANs, activity = 0.44%

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